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Readings in sustainable forest management

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Preface

This collection of technical papers on sustainable forest management had its origins in the 10th World Forestry Congress which issued the Paris Declaration in 1991. The Declaration called on the world's decision-makers to raise awareness and inform the public so that forest issues could be better understood and appreciated.

The papers have already been synthesized in a companion volume *The challenge of sustainable forest management: what future for the world's forests?* This was aimed at a non-technical audience, including decision-makers and concerned members of the general public, and it contributed to putting the Paris Declaration directly into effect.

That first, "popular" volume was based on the papers of this technical volume, but it also covered some subjects not included here while expanding on others. The contents included a discussion of the evolution of the concept of sustainability, a review of the extent of the world's forests, the reasons for their importance as suppliers of a wide range of goods and services and the options available for their management. The book recognized the conflicting interests competing for the use of forest land and highlighted the costs and benefits to society of the different choices for forest management. Chapters were devoted to laws concerning forests and trees, to forestry institutions and their role in the service of society, and to the international dimension of sustainable forest management reflected in such subjects as the role of international organizations, international agreements, the United Nations Conference on Environment and Development (UNCED), debt-for-nature swaps, the provision of genetic materials and medicines from forests and consumer boycotts of tropical timber.

A number of themes were emphasized throughout the book. These included people's participation in decision-making in forestry development that affects them and rural society, the conservation of forest resources through sound management practices and the need for forestry planning, especially the incorporation of forestry in planned land use. These themes also run through the papers included in this technical volume.

The technical papers in this book were largely prepared and submitted during the first half of 1992. The delay in publishing them arose from the decision to concentrate on the preparation and issuance of the "popular" volume, which was expected to make the most impact in the immediate post-UNCED period. It is hoped that their publication will make available to professional foresters and others valuable technical information that will be relevant to their work.

Several of the papers have been edited to reduce their length and explanatory footnotes have been added in some instances to relate the author's statements to FAO's position.

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Contents

Acknowledgements

FAO specially commissioned the technical papers comprising this volume and is grateful to the following authors who voluntarily prepared their contribution: S.S. Ajayi, E. Campinhos Jr, W.M. Ciesla, L Daryadi, J.F. de la Jara, M R de Montalembert, J. Gadant, B Hägglund, M W. Hoskins, R.H. Kemp, A.J Leslie, D.C. MacIver, D W. MacCleery, T. Michaelsen, F.S.P. Ng, M.N. Salleh, K. Ouedraogo, C. Palmberg-Lerche, H Salwasser, F. Schmithüsen, T.A. Snellgrove, M. Soto Flandez and G E Wickens

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Introduction

Forest management is defined as dealing with "...the overall administrative, economic, legal, social, technical and scientific aspects involved with the handling of conservation and use of forests. It implies various degrees of deliberate human interventions, ranging from action aimed at safeguarding and maintaining the forest ecosystem and its functions, to favouring given socially or economically valuable species or groups of species for the improved production of goods and environmental services" (FAO, 1991).

Sustainable development is defined as "...the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (ibid.).

Sustainable forest management, the subject of these papers, will thus aim to ensure that the values derived from the forest meet present-day needs while at the same time ensuring their continued availability and contribution to long-term development needs.

Until recently, foresters were often concerned to manage forests for the sustained yield only of timber or woody products. Although there were difficulties in determining the rate at which forests were growing, particularly the natural forests in the tropical and subtropical zones – and thus the volume of wood that could be harvested from time to time – and although long-term maintenance of soil fertility under certain management practices was in some instances queried, the parameters that had to be measured were nevertheless clear. "The sustainable management of forests for wood production is based on a deceptively simple principle: harvesting the wood at an average annual rate that is no greater than that at which the forest in question can grow it..." (see paper by Leslie, p. 17).

It is now realized that, if sustainable forest management is concerned with the production of wood alone, then the other goods and services that can be obtained as well as the wider social issues that may be involved, are neglected. This omission undermined the possibility of sustainable forestry management practices because, while management for sustainable wood production did in fact frequently meet these wider needs in the short term, this was coincidental and, since such practices were not included in the stated objectives, management was not done in a sustainable fashion. Wood production was sometimes in conflict with these wider functions of the forest, particularly where it competed with the needs of those whose traditional livelihood depended on the forest.

There has been a tendency to confine the practice of sustainable forest management in the tropics and subtropics to those areas of forest designated as forest reserves. In India, for instance, the provisions of the forest policy generally refer to blocks of forest that are legally constituted as reserved forests, while not including the maintenance of the forestry functions of trees growing on the remaining land area outside the reserves – an area which makes up 77 percent of the total land area. The uncontrolled use of such land is leading to degradation and erosion (Shyam Sunder, 1992). The problem is by no means restricted to India, and there is a need in several countries to extend forest policies to encompass the development of all forests, woodlands and trees if unsustainable land-use practices are to be eliminated.

The concept of sustainable forest management, therefore, must include the place of forests and trees in planned land use. The concept must define the role of the forestry sector in contributing to all aspects of development. The impacts of sustainable forestry management practices on the environment and on society must be sufficiently quantified to permit rational choices between competing interests while at the same time justifying the allocation of scarce funds to the forestry sector.

"Sustainable forest management therefore involves planning the production of wood for commercial purposes as well as meeting local needs for fuelwood, poles, food, fodder and other purposes. It includes the protection or setting aside of areas to be managed as plant or wildlife reserves, or for recreational or environmental purposes. It is concerned with ensuring that conversion of forest lands to agriculture and other uses is done in a properly planned and controlled way. It also covers the regeneration of wastelands and degraded forests, the integration of trees in the farming landscape and the promotion of agroforestry. It is a multidisciplinary task, requiring collaboration between government agencies, non-governmental organizations (NGOs) and, above all, people, especially rural people. It is concerned at local, national, regional and global levels" (FAO, 1993a).

Sustainable forest management is considered in this volume under the headings of wood production (including wood for energy), non-wood forest products, soil and water conservation, wildlife management, the conservation of biological diversity, forest protection and climate change, policy, institutional and legal aspects, socio-economic aspects and research needs. Case-studies of national policies, programmes and experiences in sustainable forest management describe experiences in sustainable forest management in a number of countries. The contributions are not, however, confined to a narrow definition of their subject matter, but recognize the multidisciplinary needs of sustainable forest management and the interrelationship between sectors.

In the first section, the "traditional" role of the forests in wood supply is treated. A.J. Leslie considers sustainable management of the tropical moist forest, M. Soto Flandez and K. Ouedraogo look at the woodlands and savannahs of the Sudano-Sahelian zone and the role of plantations is described by E. Campinhos, with particular reference to the growing of *Eucalyptus* species for pulpwood in Brazil.

Leslie's paper queries whether sustainable management is practicable or worth the considerable inputs, including funds, that are required if wood is to be the major output, in view of the apparent incompatibility between management interventions (particularly harvesting) for wood production and their effects on the sustainable supply of other goods and services. Leslie considers that the main problems are not technical (he proposes a selection system and low-impact logging) but are caused by human activity, particularly those problems arising from an inequitable world economy. A higher proportion of the returns from the management of tropical forests must be redirected from the dealers and processors back to the people who are directly dependent on the forest. Political commitment, political stability and security of ownership are other important requirements for sustainable forest management.

Forests of the tropical rain forest zone referred to in Leslie's paper comprise 718 million ha, or 38 percent of the total forested area in the tropics (FAO, 1993b).

The deforestation rate in this zone is approximately 460 000 ha yearly, or 0.6 percent of the zone. Forests of the dry and very dry zones, defined as having an annual rainfall of between 500 and 1 000 mm, cover 238 million ha, 12 percent of the total tropical forested area, but are being deforested at a rate of 220 000 ha per year, or 0.9 percent.

More than half the world's dry tropical forests and savannah woodlands are in Africa. Their management is the subject of the paper by Soto Flandez and Ouedraogo who refer to the rapid population growth in these zones which is increasing the demand for food. The area of farmland has sharply increased at the expense of forests, an effect compounded by unimproved farming methods and periodic droughts. In consequence, traditional transhumance[1] practices depend ever more heavily on woodlands for grazing and fodder derived from woody species. Woodlands are also heavily used for fuelwood production. Under these pressures, the area of woodland is inevitably decreasing, affecting not only the resource itself and the benefits derived directly from forests and woodlands, but also the wildlife resource (see paper by Ajayi, p. 81).

Soto Flandez and Ouedraogo describe the experiences of a project in Burkina Faso, where a management plan prepared for a particular area encourages people's participation in decision-making and in forest management as well as comanagement of the processing industry by the private sector. Some technical constraints exist – there is a lack of knowledge of growth rates and the area is not well protected from uncontrolled fires – but the main problems are legal and socio-economic, such as contradictions between traditional and modern landownership and usufruct practices and the need to introduce new forms of rural organization and land-use practices in place of the old ones.

The establishment of forest plantations is an alternative form of wood production that has grown rapidly in recent years. The reported gross area of forest plantations in the tropics increased from about 18 million ha in 1980 to about 44 million ha in 1990, or at an annual rate of more than 2.6 million ha (Pandey, 1992). Although there is doubt concerning the survival of the whole of the reported area, with the estimated net area in 1990 lying between 28 million and 34 million ha and the annual area established being between 1.6 million

[1]Transhumance refers to the seasonal movement of livestock to another region, as opposed to "nomadism" which refers to continual movement in search of pasture

and 2 million ha, the figures nevertheless illustrate the increasing importance that is attached to wood supply by means of forest plantations.

Plantations usually have one major objective for their establishment: generally the production of wood but sometimes also the provision of services such as shelter and protection. At the same time, plantations may provide non-wood products; however they cannot provide the full range of goods and services supplied by natural forests to which they have a complementary role.

The sustainable management of forest plantations is described in the paper by Campinhos, with particular reference to the plantations of *Eucalyptus* species at Aracruz in Brazil. He describes the increase of plantation area in Brazil under the impetus of financial incentives and stresses the present importance of forest plantations to the country's forestry economy. The example quoted is of a plantation restricted to species of the genus *Eucalyptus*, much of which is now grown from clonal material. Silvicultural and management practices that contribute to sustainable production include the matching of genetically improved material to site, the maintenance of soil fertility through the incorporation of residues, the protection of the soil from erosion, the monitoring and control of pests and diseases and the use of low-impact logging equipment. The provision of social benefits for local communities and the retention of natural woodland over 40 percent of the area, with associated native flora and fauna, are among the methods used by the pulp and paper company in their approaches to sustainable forest management.

The papers described have dealt with woody products of the forest, although recognizing the importance of the non-wood forest products and the services provided by natural forests and plantations. A number of papers then look at the range of services and other goods that can be obtained from sustainably managed forests. G.E. Wickens describes sustainable forest management for the provision of non-wood forest products, T. Michaelsen deals with soil and water conservation and S.S. Ajayi looks at aspects of wildlife management in the forest. The importance of conserving biological diversity and genetic resources in harmony with sustainable management for productive purposes is stressed by R.H. Kemp and C. Palmberg-Lerche.

The value of non-wood forest products is frequently overlooked, yet locally these may be much more important than woody products, and their outturn may be the key to involving people in participatory forest management. Wickens describes the range of non-wood forest products, including plants for food and medicinal purposes, fibres, dyes and animal fodder as well as valuable export commodities such as rattans from Southeast Asian countries and gum arabic from the Sudan. The range, and lack of knowledge, of management requirements for forest species providing non-wood products may complicate their management, and their integration with timber production may slow the outturn of logs but could make the practice more environmentally acceptable. Moreover, the income generated might cover the increased cost – thus supporting Leslie's plea for the selection system of management and low-impact harvesting practices in tropical moist forest management.

There is considerable potential for the breeding of multipurpose trees and shrubs, using the natural variation described by Kemp and Palmberg-Lerche. Yields, nutritional status or seasonal availability could all be improved in the same way as Campinhos is breeding *Eucalyptus* species for increased growth rates and pulp production.

Sustainably managed forests provide a range of environmental services as well as goods. One of the best known of these services is soil and water conservation, described in the contribution by Michaelsen. It may be the principal object of management or it may be combined with other objectives, including recreation, animal or plant conservation or low-impact harvesting. Forest plantations or mixed land use may also be consistent with the provision of catchment area protection but, in all cases, the sustainable provision of goods and services will depend on proper planning and appropriate management.

Other services provided by forests and woodlands are represented by the genetic resources of forest ecosystems, reviewed by Kemp and Palmberg-Lerche. Forests and woodlands contain a wide range of plants and animals of actual or potential socio-economic importance. Their genetic diversity buffers forests against environmental change and is the base for the sustainable development of forest resources; it is particularly important in tree improvement programmes, such as those described by Campinhos, which depend on natural variation. The genetic diversity represented by populations of marginal zones (such as the savannah woodlands dealt with in the paper by Soto Flandez and Ouedraogo) have adapted to environmental fluctuations and stress and may be more tolerant of global climate change (discussed by D.C. MacIver, p. 119). It is therefore important to include the extremes of natural occurrence in genetic conservation programmes. Genetic resources can be conserved where areas have other objectives, even timber production, but there can be no conservation without adequate control and continuity of management. The environmentally friendly harvesting techniques suggested by Leslie for the moist tropical forest will be necessary for the physical conservation of genetic diversity, while the social and economic measures, also identified by Leslie as requisites for sustainable moist forest management, will include channelling a greater proportion of the profits of forest product processing and trade to those whose way of life depends on the resource.

Several of the papers summarized above stress the need for low-impact harvesting systems, for instance for the sustainable outturn of timber and non-wood forest products, the maintenance of watersheds and the conservation of biological diversity. Studies have shown that such systems can be cheaper to operate than traditional systems but that better planning, close supervision, the upgrading of skills and improvements in rewards are needed if they are to be effective (Dykstra and Heinrich, 1992). FAO's Programme on Environmentally Sound Forest Harvesting will compare conventional harvesting methods with improved technologies that are environmentally and economically acceptable, in Latin America, Asia and Africa.

The paper by Ajayi deals with the goods and services from the forest (in this case from similar woodlands to those described by Soto Flandez) by discussing the sustainable management of wildlife resources in Africa. Although wildlife has a high value, both to rural people through the provision of meat and employment and to the national economy through game ranching and tourism, wildlife is nevertheless under serious threat. Attempts to conserve wildlife through repressive laws and the alienation of the rural people from an asset to which they consider they should have free access has had a negative effect on the resource, since the people no longer identify the resource with the sustainable fulfilment of their requirements. There is a need for wildlife utilization with local community participation, particularly by ensuring that the benefits accrue to the rural communities.

Sustainable forest management is affected by external influences such as fire, pests and disease in the short term and may be affected by global climate change in the long term. These subjects are discussed in papers by MacIver and W.M. Ciesla.

Potential changes in the global climate are caused by the increased release of greenhouse gases, such as carbon dioxide. Most of the increase in atmospheric carbon between 1850 and 1986 was derived from the burning of fossil fuels, with less than 40 percent of the cumulative input estimated to have come from deforestation and changes in land use (Watson *et al.*, 1990). MacIver outlines a climate plan for sustainable forest management, including forest climate management (the identification of shifting seed zones, pollen flow and contamination, site modification technologies, tree breeding and the conservation of genetic resources and enhanced forest protection) and greenhouse gas management. The plan stresses the continuing role of forests in reducing concentrations of greenhouse gases through carbon sequestration.

The protection of forests from fire, insects and diseases is described by Ciesla. Protection must be considered an integral part of sustainable forest management, since these harmful agents can affect the flow of goods and services from the forest. Increased levels of carbon dioxide in the long term could increase forest growth and susceptibility to damage from external causes.

Policies that can be implemented, laws that can be enforced and institutions that are capable of meeting their responsibilities are requirements for sustainable forest management. In the paper by M.R. de Montalembert and F. Schmithüsen, the dynamic nature of rural development is stressed, leading to the need for a continual revision and updating of forest policies, institutions and regulations to maintain an effective framework of incentives for the practice of sustainable forest management. While this framework should be flexible, it must nevertheless offer the necessary security for long-term commitments in forest management (a point also made by Leslie and Kemp and Palmberg-Lerche). The changing role of the public sector and the expanding role of the private sector, including NGOs, must be considered in adapting institutions and organizations. The strengthening of technical skills, the reinforcement of the social basis for sustainable management and the diffusion of information are essential but the most important factor in the move towards sustainable forest management will be changed attitudes towards more comprehensive and partnership-oriented techniques.

The partnership approach is expanded in the contribution by M.W. Hoskins to include socio-economic aspects of sustainable forest management. It applies where people living in or close to the forest (insiders) carry out wise forest and tree management practices with adequate support from, or in partnership with, outsiders (such as foresters). In other words, the insiders are doing all or some of the managing and the outsiders are acting in a service role. It is where the respective roles of the parties in the partnership approach are misunderstood or misapplied that participatory approaches have failed, and policies, laws (including land tenure and usufruct legislation) and organizations may have to be adapted to meet these requirements. Furthermore, forestry extension and research will have to develop the means of stimulating a two-way flow of information to and from the users. The concept of the ideotype, or identification of the functions of the desired tree, has been an important advancement in this field and has links with tree breeding and the conservation of genetic resources.

The need for research in support of sustainable forest management is reviewed by M.N. Salleh and F.S.P. Ng. They note that a long-term commitment to research is required, but recognize the difficulties of maintaining that commitment for scientists and institutions in tropical developing countries where funds and support services are often inadequate.

Five case-studies of countries in which the forestry sector makes an important contribution to the national economy and frequently also to export earnings conclude this volume: they are on Chile (J. F. de la Jara), France (J. Gadant), Indonesia (L. Daryadi), Sweden (B. Hägglund) and the United States (H. Salwasser, D.W. MacCleery and T.A. Snellgrove).

Chile has large reserves of native forest and plantations, the latter making an important contribution to the national economy through internal sales and exports. De la Jara identifies a lack of knowledge of the state of the forest resource, the emergence of environmental issues connected with large-scale industrial roundwood plantations and competing interests of various groups as some of the constraints to sustainable forest management in Chile. On the other hand, forestry programmes are often the only channel for the provision of social benefits in rural areas. De la Jara draws attention to the weak state of forest institutions resulting from insufficient funding, the effects of which include the inability to enforce legislation, manage state-owned forests, carry out research or provide technical support to small forest owners.

Indonesia, like Chile, has a forestry sector which makes an important contribution to the domestic economy and to exports. In this case, the benefits are largely derived from natural forests. The demarcation of the permanent forest estate is proceeding and land is under pressure from a rapidly increasing human population. Shortages of trained staff and workers and a weak administration have slowed down programmes in plantation establishment and the rehabilitation of degraded forest. The definition of responsibility for forest management among central and local governments and the private sector has also caused some problems. Environmental concerns of pressure groups in timber-importing countries may affect Indonesian exports of wood products derived from natural forests. In the past, there has been an emphasis on logging rather than management, with income being invested in forest industries and in non-forest activities. The adoption of a national forestry action plan (within the framework of the Tropical Forests Action Programme) will help to overcome weaknesses and to develop systems for sustainable forest management.

Gadant identifies three important factors contributing to sustainable forest management in France: well-trained personnel, adequate research facilities and appropriate funding that, through fiscal and financial incentives to the private sector, takes account of the long-term nature and relatively low productivity of forestry. Lands are permanently allocated to forestry and there is continuity in the national forest policy, although management has largely been decentralized in recent years. Private forest owners are very important in France, where one family in five owns a wooded area, and there is a large contribution to the forest estate from farm forests. District forestry also has a long history, with one commune in three owning some forest. Nevertheless, French society is becoming increasingly urbanized and requires more from the forests than just production. As a result, there is an increasing need to maintain a channel of communication between those who manage the forest patrimony and those who appreciate its scenic and cultural values. Gadant makes the important point that conservation requires management; it is not just preservation through total protection.

In Sweden, the ecological conditions are not favourable for forest growth, yet the forestry sector and the export of forest products are very important to the national economy. The history of social and industrial development in Sweden shows many of the problems currently afflicting sustainable forest management in developing countries, although the

Swedish forest estate is now under stable ownership – three-quarters is privately owned – with long-established legislation leading to its sustainable management, first for industrial wood and later for other benefits. Examples of problems formerly affecting the Swedish forests include disregard for forest laws, exploitation of the forest owners by industrial users and the movement of landless people to cities. The Swedish experience has been one of social consensus, with society investing through financial incentives and stability, during which time the forest resources were constantly improved. Today there are signs of conflict between various interest groups, however, which must be resolved if the resource is to be sustainably managed.

A heightened awareness of forestry issues in the United States has led to major changes in the way in which an increasingly urban public perceives the role of forests and their management. The "spotted owl debate" and the change of policy towards retaining "old growth forest" will have environmental, social and economic implications outside the northwestern United States as the source of wood is switched elsewhere – with effects on global biological diversity – or as substitutes, which may use more energy in their production, are introduced. The Forest Service of the United States Department of Agriculture has responded to public pressure on management policy issues through a programme concerned with the management of the national forest system. The programme has four primary purposes: to deepen knowledge of methods for the sustained yield of multiple current and future benefits; to improve public participation in making decisions on the use of resources; to strengthen links between research workers and managers; and to integrate all aspects of land and resource management.

In summary, the common feature of the discussion of sustainable forest management by the papers presented in this volume is that timber production should not be the sole aim and that the sustained provision of a wide range of environmental, social and economic needs must also be included.

Active management is required for forest conservation and the sustainable production of goods and services. The preservation of forest resources through strict protection and non-intervention will not sustain those resources because natural systems are themselves subject to evolutionary change and succession. Salwasser, MacCleery and Snellgrove quote the case of old-growth Douglas fir forest in the western United States, which is the habitat of the northern spotted owl. In fact, this forest is subclimax, which means that, unless managed, it will eventually move towards different forest conditions not necessarily suitable for the northern spotted owl. The conservation of the genetic diversity of plants and animals in all successional stages and types of forest will require management interventions, with greater action being necessary for those that are habitat specialists or, in other words, are solely adapted to a particular habitat.

Sustainable forest management can only be practised if the goods and services obtained are seen as contributing to rural development and if local people participate in the decision-making process to set objectives as well as, where appropriate, in the management of the resource. Partnership between "insiders" who carry out the management and "outsiders" who support those activities is essential. A greater proportion of the returns from forest management must flow back to the rural people. In some developed countries this occurs because a high proportion of the forest estate is under individual or communal ownership.

Not only those who depend on the forest for their livelihood will participate in decision-making and management. In developed countries, much of the population is urban but still has a keen interest in the fate of the forests. An improved two-way flow of information is needed between foresters and the people affected by the foresters' decisions.

There are still several infrastructural constraints to sustainable forest management, including administrative arrangements, laws and policies that fail to provide incentives for tree planting. There is a need for new attitudes towards participatory forms of forestry, interactions with other types of land use and the role of forestry in overall rural development.

Technical knowledge is currently lacking, even in developed countries, but this will be obtained sooner or later through research and investigation. The development of low-impact logging techniques is needed in the moist tropical forests in particular, in order to minimize impacts on non-wood forest products, regrowth, protective functions and biological diversity.

Sustainable forest management requires planning, which needs reliable data and a foundation of research as well as increased information at all levels. The inclusion of forestry in land-use plans is essential, but other forms of land use that interact with forestry must also be sustainable; for example, sustainable forestry will be impossible without sustainable agriculture which will in turn require programmes to limit human population growth.

The case-studies of two developing and three developed countries show the lack of funds and trained staff in the former but they also show that environmental concerns expressed by vocal pressure groups are by no means confined to the developed world and that there are linkages between the two country groups through trade boycotts threatened by consumer groups in the industrial countries. Many of the papers refer to the need for political commitment and stability in the management of the resource and, in the countries mentioned, for forestry investment incentives.

The papers presented in this volume are meant to provide an effective and constructive basis for the development of policies and programmes that will lead to sustainable forest management in all types of forest. It is hoped that they will contribute not just to increasing the technical understanding of those within the forestry profession, but also towards the political commitment and heightened awareness of the complexities of forestry issues of those outside it.

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Part 1

Developing systems for the implementation of sustainable forest management

Sustainable management of tropical moist forest for wood

A.J. Leslie

This paper discusses the feasibility of sustainable management of tropical moist forests for wood production. Emphasis has shifted from considering sustained wood yield as being necessarily the same thing as overall sustainability. The concern is now with sustaining the forest and all of its values rather than just its wood-producing capacity. Although it is difficult to combine conservation with a potentially destructive use such as timber harvesting, it is not impossible. This paper reviews the complexities of sustainable forest management and its components, and reviews experience in Malaysia and in West Africa. From this the determinants for success are identified and the prospects for sustainable forest management in tropical moist forests are discussed. The development and introduction of low-impact management techniques, particularly for harvesting, are stressed.

A reasonable doubt?

One of the main concerns over what is happening to the world's tropical forests is the apparent failure to manage forests sustainably. The evidence seems to confirm this. A well-balanced review of the status of sustainable management in tropical forestry (Poore *et al.*, 1989) found no more than a negligible proportion of forests being managed to the review's standard. Worse still, much of it was in an area of northern Queensland, Australia, which had been recently withdrawn from wood production. More detailed studies of specific areas have since indicated that the proportion is probably somewhat higher than that reported in the review (e.g. ITTO, 1991). Nevertheless, even the addition of these areas is unlikely to give a proportion of much more than 5 percent as areas of the world's tropical moist forest under management that may be recognized as sustainable.

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The actual figure is, of course, debatable. There is not enough agreement on either the total area and composition of tropical forests or the definition of sustainable management to warrant much precision in any such estimate. Certainly, the proportion that could be claimed to be managed for sustained yield is much higher than 5 percent. That figure may not, however, be too wide of the mark for truly successful sustained yield management. In fact, a great deal of experience in tropical forestry tends to support the scepticism about forest management sustainabililty as practised at present (Jacobs, 1988; King, 1990).

The issue can be divided into three questions:

- Is sustainable management possible when wood is a major output?
- If it is, how can it be implemented?
- Is it then worth the effort and the cost?

Recent reviews (Schmidt, 1987; FAO, 1991a; Perl *et al.*, 1991) cover the issues, possibilities, differences and remedies pertinent to the first two questions.

The contribution of this paper is to explore the implications of the third question for forest management in light of the apparent gap between sustained yield for wood and multipurpose sustainability.

Sustained yield and sustainable management

The science and practice of forestry is largely a response to the first two questions, modified to varying degrees in light of the third. Its essence is the simultaneous conservation and use of forests for the welfare and development of human societies. Some uses are best or most easily provided by leaving forests more or less intact, and management sustainability for these purposes poses no great problems other than protection and occasional manipulation. The difficulties arise mainly from attempts to combine conservation with potentially destructive uses. The most prominent and potentially the most destructive of these, apart from conversion to other forms of land use, is using forests for wood production. It is not the only destructive use and wood is far from being the most important product of either tropical or temperate forests, but the destructive potential of wood harvesting is such that much of the technical content of forestry is concerned with conserving forests while using them as a permanent, renewable source of wood.

The sustainable management of forests for wood production is based on a deceptively simple principle: harvesting the wood at an average annual rate that is no greater than that at which the forest in question can grow it and without harming the forest's capacity to supply other goods and services. This applies for any type of forest anywhere and at any time, irrespective of whether wood is a primary or a subsidiary objective of management.

The principle is, however, much easier to state than to apply. The increment, being physically inseparable from the trees with which it is produced, must be harvested by felling a part of the forest equal in amount to the increment of the forest as a whole. The problem of sustainable management arises from the difficulties of coordinating the four elements involved: ascertaining the increment; identifying the appropriate part of the forest to be felled as being equivalent to the increment; replacing that part of the forest to be felled in conjunction with the harvesting operation; and harvesting so that no serious and permanent damage results to other goods and services or to the forests' capacity to continue supplying them in the future.

The traditional sustained yield management systems did combine the first three elements in a way which met sustainability requirements at the time. The methods of yield regulation developed to implement sustained yield have since become operationally obsolete with the development of computerized stand and growth modelling. However, the principle itself still holds, despite a strong tendency nowadays to urge its abandonment on the grounds that it no longer serves practical needs or meets the standards of economic efficiency. Yet these arguments appear less plausible on closer examination of their narrow interpretations of sustained yield and criteria of efficiency. Although the questions they raise are relevant to the application of sustained yield, they are far from decisive in dismissing the principle.

The fourth element is a fairly recent development. It reflects the fact that a sustained yield of wood is no longer accepted by influential sections of the general public and the world community as being necessarily the same thing as overall sustainability. The concern is now with sustaining the forest and all of its values rather than just its wood-producing capacity.

The complexities of sustainable management

The first two elements taken together cover the yield regulation part of a sustainable management system, the third the regeneration or silvicultural part, and the fourth the harvesting part. In practice, it is not easy to devise, measure, apply or monitor any one of these, and the difficulties are compounded because all parts have to work together and simultaneously. The difficulties increase with the ecological and structural complexity of the forests to be managed and their economic and social environment (Janzen, 1975).

It seems to be universally agreed that, ecologically, the tropical moist forests are among the most complex of terrestrial ecosystems. This could partly account for the limited success of sustainable management in tropical forestry and is undoubtedly the ultimate limiting factor. As yet, however, it is still less of an obstacle than socio-economic problems arising from the use of tropical moist forests for industrial wood production.

The economies of developing countries to which the tropical forests are virtually restricted are, by definition, simpler than those of most temperate countries, but the task of economic management is vastly more complicated. The task of combining economic development with social justice is daunting on its own, without the added handicap of having far fewer options than modern developed countries had at a similar stage in their development.

The spatial assessment of sustainability

The consequent and somewhat necessarily ad hoc nature of economic planning under the above circumstances is rarely favourable for sustainable management of forest resources. Management plans can be easily overridden by the more powerful political and social appeal of such considerations as income and employment generation or foreign exchange earnings. Hence, it is hard to meet the initial requirement for sustained yield management: the delineation of a specific tract or group of tracts of forest as the sustained yield unit with reasonable security of tenure and stability of boundaries and for which the sustainable yield of wood can be calculated, harvested and monitored. If this cannot be done, sustainable management is severely handicapped from the outset. Yet strict stability and security of the unit are not absolute conditions for sustainable management. Changes in either or both can be accommodated in management planning and control, although only when any additions or reductions in the area and changes in the forest composition and structure are fairly predictable.

For various reasons, however, neither stability nor predictability is achievable in most developing countries. Far too many factors can lead to greater unpredictability than can be accommodated: forest clearing for controlled expansion and diversification of agriculture, for infrastructural needs or for unplanned, poverty-driven subsistence farming, and excessive cutting for immediate liquidation of capital for national development or simply for the personal enrichment of those in authority. Whatever the cause, the result is that the area and composition of any sustained yield unit are likely to be upset, making sustainable management not only difficult but impossible.

Most critics of forestry's failure to live up to its fundamental principle of sustainable use consider either a country, e.g. Malaysia or a region, such as the Amazon, or even the world as the sustainable yield unit. These may be useful as polemical devices or in macro-economic planning, but they are hardly relevant to actually managing the forests sustainably. As a rule, the national resource is simply too unwieldy an area to work with as a single sustained yield unit.

The components of sustainable management

Only with a well-defined and stable sustained yield unit is it sensible to estimate the allowable cut, i.e. the average quantity of wood that can be harvested from the unit, annually or periodically, under sustainable management. The sustainable yield results from a combination of the following four elements:

- the wood increment over the unit as a whole;
- the distribution over the unit of the age or size classes of the trees producing the type of wood required;
- the methods used to replace the trees removed in the harvesting area;
- safeguarding of the supply of other products and services and respect for the other parties with interests besides those of wood production, especially during harvesting operations and silvicultural treatments.

The second and the fourth elements warrant special mention. The second governs the extent to which and for how long the allowable cut, whether greater or less than the increment, would need to be harvested in order to bring the sustained yield unit into the balanced state, allowing a cut equal to the increment to be maintained indefinitely or for as long as conditions remain unchanged. The fourth sets the limits within which all silvicultural and logging operations associated with sustained wood production must be conducted. These limits, in turn, govern whether wood production under those conditions is economically viable. If it is not, then any wood harvesting, even within the sustained yield limits, would either be unprofitable, and therefore tend to be implemented with scant regard for the standards of sustainable management in the full sense, or would have to be subsidized.

If the two elements interact, it is in one direction only. An allowable cut at a higher level than the increment may be set where the size-class distribution is skewed towards the larger classes. This greater cut could go some way to compensating the higher harvesting costs forced by the restrictions needed to safeguard non-wood products or the interests of local communities or environmental values. A distribution skewed in the opposite direction, however, requires an allowable cut set lower than the increment, thus tending to push logging costs even higher.

There are generally few short cuts to measuring increment in tropical moist forests. The constraints on establishing age of tropical trees are not perhaps as absolute as they were once thought to be (Baas and Vetter, 1989). However, even a moderately reliable basis for increment measurement still depends heavily on repeated measurements (e.g. Lowe, n.d.) which, given the erratic growth patterns of individual species and size classes (e.g. Fox, 1976), must cover very long periods of time. Apart from the length of time before the necessary information can come from the permanent sample plot system, and during which changes in methods and instrumentation are likely to jeopardize comparability, the system and records are expensive to maintain and require a level of stability and continuity that few countries can provide. It is effectively by default that approximation, estimation and extrapolation from the few sets of usable data have become more or less the standard procedure.

Indications are that mean annual increments of between 1 and 3 m^3 per hectare of wood to the specifications for industrial use safely represent the pantropical range (Dawkins, 1958; Nicholson, 1979; Poore *et al*, 1989). Whatever estimate is adopted for forests in the sustainable yield unit, the increment problem becomes that of determining the most appropriate part of the forests to harvest as surrogate for the total increment of wood over the whole unit. Three classes of trees should qualify:

- those at the stage of maturity corresponding to the target product specifications;
- those whose removal would favour or accelerate the growth or development of younger or smaller trees better suited to producing the desired end-products;
- those that should be salvaged before they die or are lost for one reason or another.

Such standards in the process of sustained yield management presuppose a knowledge of the forests and their structure and condition far beyond the present realm of practicality in tropical forestry for wood production on a bulk scale. However, it is not at all impractical when the harvest focuses on one or a few high-value species, as in the teak management system devised by Brandis in the mid-1860s (Brasnett, 1953).

Without such unique conditions, the problem has usually been resolved by applying a simple area control system of yield regulation. The unit is divided into a series of coupes equal in number to the years either in the technical rotation adopted for the principal timber species or in the estimated felling cycle during which trees below the specified standard for harvesting are expected to reach it. The method involves first choosing a minimum diameter at which trees will be deemed ready for harvest and then estimating either the time it will take for a tree of each species to grow to that diameter from seed or shoot or the time it will take for trees of specific diameter classes below that minimum to grow into the mature diameter class.

The method requires some knowledge of the size-class distribution over the forests in the unit but in no greater detail than a fairly low-level timber inventory would provide. It also requires some idea of the diameter growth rates by species and by size class. But more important, it requires a fairly consistent and unwavering system for monitoring the actual growth and changes in species composition and stand structure against the initial guesses, as well as the power and ability to revise the cut in the light of new information.

Given these conditions, the method has been found to be a safe way of sustaining wood output with two provisions: that no drastic alterations are made to the area of the unit and that regeneration is assured.

Lessons from experience

The Malaysian Uniform System in the lowland forests of Peninsular Malaysia met the above standards until the conversion of the majority to agricultural-based development virtually eliminated these forests as a timber resource. It was able to do so mainly because it released already established regeneration, and then only until the expanding scale and increasing mechanization of logging made it too costly to operate and administer (Wyatt-Smith, 1963).

Attempts to transfer and adapt this system to West Africa were markedly less successful. This was less the result of mechanized large-scale logging than having to rely more on inducing rather than releasing regeneration. Whatever the reason, the canopy openings and the pre- and post-felling treatments were rarely followed by the regeneration on which sustained yield depends. As it happened, this limited success hardly mattered. Most of the forests in which management was attempted – with the exception of many of the forest reserves in Ghana – have subsequently been lost to agriculture or converted to forest plantations.

This West African experience may well underlie the widely held opinion that plantations offer the only reliable means for sustained yield management in tropical forestry. However, the main value of this contrast between results from similar systems is probably what it reveals about the determinants of successful sustained yield management of tropical moist forests.

Determinants of success in forest management

Three factors seem to be crucial. One is the interaction between the yield regulation and the regeneration parts of management. Under ecological conditions in which the primary function of the canopy openings is to release already established regeneration, simplifications in yield regulation by area are less risky than when the openings must induce the regeneration.

The second factor is the typically uneven structure of most tropical moist forests. In this structure, neither size nor position in the canopy is a reliable guide to relative maturity of the many species in the highly variable forests. Silvicultural selection systems in association with more direct volume control seem to be a safer and more logical basis for sustained yield management. The success of sustained yield management along these lines in Ghana (Baidoe, 1970) tends to confirm this.

The third point is probably the most compelling: the economics of logging, under prevailing market and commercial conditions, virtually dictates forest management possibilities for most of the tropical moist forests. It alone is enough to rule out sustainable management consistent with the biological, structural and other social factors as a feasible proposition, while making even sustained yield management primarily for wood a doubtful one. This is because these market structures and patterns as well as the accompanying commercial relationships force operators into high-output, heavy-technology, short-cut logging systems. These are physically and economically incompatible with management systems that, for sustained yield, depend on following the regeneration or on carefully calculated and controlled canopy openings in order to induce regeneration. They are even less compatible with the standards that must be met under sustainable management for products and services other than wood (see list in Jacobs, 1988).

Prospects of making the transition to sustainability

This transition from attempted sustained yield management for wood to successful sustainable management in a broader sense is now the main challenge in tropical forestry. It is, some argue, an impossibility (Jacobs, 1988). It is common knowledge that sustained yield management for wood has been and still is extremely difficult to implement. It seems logical to infer from this that there is even less chance of successfully combining a sustained yield of wood with the unimpaired production and protection of the many other non-wood products, services and values involved in sustainable management.

For all of its plausibility, the argument does not stand up. It depends mainly on the technical difficulties of applying sustained yield management, but these are not yet the major limiting factors. The present obstacles are much more the result of a malfunctioning, lopsided and inequitable world economy. Unless a way can be found to escape from the economic stranglehold on tropical forestry, management for sustained yield wood production is barely a realistic target, let alone sustainability in all its facets.

The radical solution in this sort of situation is to change the system that causes it. As this is hardly something that the forestry sector has the power to do, work must be carried out within an imperfect system. This means either accepting the limitations and the very few opportunities they offer sustainable management in tropical forestry or hanging the response to these limits. The first option is not as inevitable as most commentators seem to believe. The prospects for a different response are, fortunately, better for the tropical moist forests than they are for most other forest types. Ironically, this is largely a result of the pressure that the necessity to meet sustainable management standards places on logging.

Sustainable management framework for wood

Conceptually, the technical characteristics of tropical moist forests can be combined with the markets for tropical woods and other non-wood products to turn what is a threat in most other types of forest into an opportunity.

There is no question that sustainable management of tropical moist forests is relatively easy if they can be effectively protected from fire and conversion to other forms of land use and if they are not then commercially exploited for industrial wood. If, and it is a very big if, the first two conditions are met, then the problems will arise almost entirely from commercial wood utilization. Timber harvesting, even under effective sustained yield management for wood, puts most of the other aspects of sustainable management at risk simply because, especially as currently practised, it disrupts the forest structure, the forest and social environment and the ecosystem far more than any other use except agricultural clearing.

The conclusion is inescapable: if sustainable management is to include industrial timber production, sustained yield management for wood must be combined with very low-impact harvesting. To qualify as a low-impact system, harvesting has to be conducted under the following conditions:

- the felling of very few trees per hectare;
- negligible damage to the residual stand, any advanced growth and already established regeneration;
- retention and protection of trees, shrubs, vines, palms and ground flora that have actual or potential commercial or handcraft value, an ecological or cultural significance as food or wildlife or importance in environmental, stream bank and soil protection or the conservation of biodiversity, or that serve as links in food, pollination and seed dispersion chains.

These are minimum conditions which, in turn, impose four additional conditions on any logging system:

- No heavy machinery for skidding is to be used.
- Careful and accurate directional felling should be carried out.
- Road and extraction routes are to be planned, designed and constructed to conform to standards for environmental protection and social and cultural welfare rather than primarily to minimize log transportation costs. This implies narrow road line clearings, avoidance of vulnerable slopes and sensitive localities, a minimum of earth movement and the highest standards for surfacing, maintenance, drainage and stream crossings as well as camps and settlements.
- Operations are to be suspended during wet weather and for some time afterwards.

One inevitable consequence will be greatly increased harvesting costs compared with those of most current operations.[1] Whether the markets for tropical timbers can absorb the extra cost or whether there is enough economic rent in the marketing chain to allow it to be absorbed are, therefore, matters of considerable debate. The costs of low-impact harvesting are the unavoidable price of sustainable management. Either it is absorbed or else wood production, even under sustained yield management, has no place in sustainable management in tropical moist forests. The decisive question is not the most hotly disputed one at all: it is not whether sustainable management for wood production is possible, but whether it is worth the effort and the cost.

Three crucial implications for forest management follow. First, only management based on some form of selection silviculture can generally be consistent with low-impact harvesting; second, harvesting will have to revert to low-powered systems[2] in which planning and highly skilled operators are substituted for the high-power, high-output systems characteristic of present harvesting (Tropical Science Centre, 1982); and third, management will therefore have to concentrate only on those species that now command or could command prices high enough to carry the costs of low-impact harvesting.

Feasibility of low-impact management in wood production

Not only does the feasibility of low-impact management seem to rest on a return to the despised practice of high grading,[3] but it also implies that the considerable effort expended to increase utilization of lesser-used species is misguided. The first danger is a real possibility if the system were to be run on the simple diameter-limit basis common to most of the so-called selection systems in the tropics. To prevent the focus on high-value species from degenerating into a device for high grading, the diameter limits corresponding to the technical rotation for the target species and the target products should be guiding rather than binding. In the selection of trees for harvesting, therefore, silvicultural considerations must override the diameter limits. The allowable cut could thus

[1] Studies quoted in Dykstra and Heinrich (1992) show that environmentally sound harvesting methods can be less costly than conventional techniques

[2] High-powered systems need not be high-impact Likewise, the implied prohibition on the use of heavy machinery for skidding could eliminate a technique that might be appropriate under particular circumstances.

[3] Described as "cutting the best and leaving the worst", from a practice common in the hardwood forests of the United States in the nineteenth century.

include some trees below the diameter limits as well as some above them. The ruling criterion would be improved productivity potential in the broadly defined sense and not present marketability.

The second implication is correct. It would be wrong only if a virtually impossible combination of conditions prevailed, such as the following:

- the extra volume harvested with the more intensive utilization of lesser-used species would have to improve the financial revenue-to-cost ratio substantially;
- silvicultural systems approaching clear-felling would have to be generally applicable;
- harvesting under such systems would have to have a negligible adverse impact on all other products and values.

The combination of the latter two conditions comes close to being a contradiction in terms, while support for the first lies more in hope than in evidence.

The likelihood is that only selection-type management systems for a few high-value species can possibly satisfy the conditions. Even then, sustainable management to these limits is not necessarily feasible. The chances of their being ecologically, socially and environmentally feasible are quite good, provided regeneration can be assured.

The same thing cannot be said with comparable confidence for technical and economic feasibility, however. A high and continuous input from very skilful and knowledgeable staff, both technical and professional, is a prerequisite for the precision necessary in tree selection, increment and growth rate assessment and regeneration as well as overall planning and monitoring. The standard required is close to that of the method of control described by Knuchel (1953). This alone might appear to put it right out of the technical reach of most developing countries as neither the staffing nor the continuity standards can be readily met.

The chances of such systems being economically feasible might seem to be even lower.[4] The apparently higher costs of management necessary to attain the high technical standard required would be added to the higher logging costs involved in harvesting lower volumes per hectare under more stringent standards for protecting other values. The cumulative result would almost certainly push the costs of most operations as currently practised well beyond anything that could be absorbed within current markets.

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[4]See footnote 1, p.27.

The path to low-impact management

In this line of argument, the low-impact system hardly seems to be a viable way to sustainable management, but to reject such a system because of its technical and economic impracticability also precludes wood production as an output under sustainable management. The point cannot be made too often: sustained-yield wood production must be low-impact as well as profitable. If this is not possible, wood production has no place in the sustainable management of tropical moist forests. However, this defeatist conclusion only applies, if the assumptions about costs and markets on which it depends are correct and cannot be changed. There is no reason to accept that either is true.

For a start, not all changes in harvesting methods increase logging costs. The simpler technology adopted means less capital-intensive logging systems with lower fixed costs in total and per unit area. The reduced volumes harvested per hectare do not, therefore, necessarily involve as big an increase in the unit cost of logging as under the present logging systems. Nor, for the same reason, would adjusting to the more stringent standards for the protection of environmental, cultural and social values increase current costs as much. Undoubtedly, an increase in logging costs is inevitable under sustainable management, but not to the extent implied by simple extrapolation from present methods and systems.

Similarly, the higher technical standards for the more intensive forest management under these systems would inevitably cost more in professional and technical staffing numbers and quality and in their field support, but this does not necessarily mean a proportionate increase in the cost per unit of wood output. Inventory and monitoring of wood production would only have to cover the few target species rather than the several hundred under management at present. Furthermore, an increase in staff and other resources directly involved in forest management does not necessarily mean an equivalent increase in costs overall. Many state and national forest services have plenty of scope within their existing structures to redeploy qualified and experienced staff as well as support services to the field since, ultimately, the quality of forest management depends on what happens in the forests more than on what is planned in head offices. This is particularly true of forest management for wood production, which has to meet the standards of multiple-use sustainability. The best people should be located where those standards are most vulnerable.

Increased management and logging costs are inevitable under sustainable management but not to the extent indicated on first sight.

However, the weakest part of the argument against the practical feasibility of low-impact management is probably its assumptions regarding revenue. Even with smaller additional costs, doubts about the market's capacity to absorb them are quite legitimate under present marketing arrangements. The trouble is that segregation of high-quality from the utility timber tends to occur more towards the consumers' end of the marketing chain than the producers' end. The returns from higher-valued timbers are thus captured more by the dealers and the users of tropical woods than the growers. The evidence to that effect is naturally indicative more than definitive, but studies of economic rent (Gillis, 1988), the extent of transfer pricing (Barnett, 1989) and the structure of markets for high-quality tropical timbers (OFI, 1991; FAO, 1991b) all point in that direction. The price differentials and the levels of economic rent seem to be quite capable of absorbing the additional costs of sustainable management provided they can be redirected to the forest end of the marketing chain.

This would involve a complete restructuring of the tropical timber marketing process, moving away from its present commodity mode to a specialty, custom-based orientation. Undeniably, the continuity of wood production from tropical moist forests depends ultimately on whether it can adapt to the standards for sustainable management. It is no good arguing that the pressures arising from international concern can only bear on the export trade, which is now the lesser part of total production. Pressures from the world plantation resource now approaching maturity are just as likely to have a similar effect in domestic markets by forcing the price ceiling for commodity grades from natural forests so low as to leave no option but specialization.

Therefore, the development of high-value marketing strategies is the first step in making tropical forest management for wood production sustainable, while the market research on which the move will be based has now become the most urgent need in tropical forestry.

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Management of woodlands and savannahs in the Sudano-Sahelian zone

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This paper discusses one of the most progressive projects dealing with the management of natural forests in the Sudano-Sahelian area and undertaken in Burkina Faso betwen 1986 and 1993. Expected results include management of 200 000 ha of village areas and comanagement of 100 000 ha of forest formations with local farmer participation and the regular production of 50 000 m³ of fuelwood per year from 1993.

The paper also describes the agro-ecological and population characteristics of the Sudano-Sahelian zone. The current state of natural woody vegetation is reviewed along with utilization patterns while other practices in managing natural forests in the region are outlined.

THE SUDANO-SAHELIAN ZONE

Agro-ecological characteristics

In the semi-arid zone south of the Sahara, the climate is characterized by a long dry season lasting from eight to ten months. The only rainy season, concentrated in August, sets in with the south-western monsoon after the resurgence of the intertropical front. Mean annual rainfall increases towards the south. Three agroclimatic zones can be distinguished: a rangeland area with rainfall below 200 m; a precarious dry savannah farmland area with mean rainfall of 500 m; and an area corresponding to the Sudano-Sahelian zone, where the natural vegetation is of the tree and shrub savannah

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type and mean rainfall is between 500 and 1 200 mm. These averages cover a wide range of annual rainy season lengths, annual rainfall totals and rainfall distributions in space and time. Rains come mostly in the form of storms; their force is considerable and causes abundant runoff and a very high risk of erosion. Wind erosion is particularly intense in the region where annual rainfall is below 600 mm at the start of the growing season and where soils are denuded (Pieri, 1989).

The dominant elements of the Sudano-Sahelian landscape are the indurated pediments that form a framework through which run, north of the 12th parallel, the dune systems that stretch from the Atlantic Ocean to the Sudan (Bertrand *et al.*, 1985).

The most widespread soils are dune soils on ancient or recent aeolian sands and pediment soils that develop on the long slopes linking an uphill area and a lowland or river. The soils of the highlands result from the combined action of palaeoclimates and erosion cycles.

The natural vegetation is composed mainly of mixed forest-grassland formations, crossed by riparian formations along the lowlands and rivers. Among the mixed-formation woodlands, there are woodlands and tree savannahs with a more or less closed canopy.

Population and economic activities

The socio-economic development prospects of the Sudano-Sahelian zone involve 16 countries: Benin, Burkina Faso, Cameroon, the Central African Republic, Chad, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Mali, the Niger, Nigeria, Senegal, the Sudan and Togo. Extending over 3 million km^2, the area currently has a population of 25 million, a number that will probably double by the year 2010 as the average population growth rates seem to have stabilized between 2.7 and 3 percent per year (Pieri, 1989). Meanwhile, the food deficit is growing while agricultural and animal production methods are not evolving. Farm production is still based on slash-and-burn practices. Three or four years of field cultivation are followed by several years of natural fallow to allow the soil to recover its fertility. As soils are depleted and space is reduced, farmers are forced to emigrate and clear new lands in areas that are still forested. The nomadic type of cattle production practised is more a way of life than an economic activity. It still depends on climatic hazards and on the tightness of the meat market. It is also becoming more and more marginalized because of the expansion of farmlands.

Although seldom quantified, the main

forestry activity is merely the gathering of forest products and fuelwood left over from clearing activities and the passage of forest fires. Wood production from natural forests is still at the experimental stage and processed products are limited to small quantities of sawnwood, except in Côte d'Ivoire, Ghana, Nigeria and Cameroon that have closed broad-leaved forests.

CURRENT STATE OF NATURAL WOODY VEGETATION

Forest formations

The mixed forest-grassland formations typical of the Sudano-Sahelian zone include: woodlands, wooded savannah, tree savannah and shrub savannah. The wooded savannah and woodlands, with tree heights exceeding 15 m, are represented by patches scattered here and there in the savannah. Wooded savannah is considered to be the degradation facies of woodlands. The tree cover, occupying 40 to 90 percent of the surface, includes *Isoberlinia doka*, *Uapaca togolensis* and *Anogeissus leiocarpa* forests. The tree savannah has large areas of grasslands. The most frequent species are: *Parkia biglobosa*, *Daniellia oliveri*, *Khaya senegalensis*, *Butyrospermum parkii* and *Detarium macrocarpum*. However, the floral composition as well as the number of stems per hectare, the diameters and the average heights vary according to climate, types of soil and human pressure. Shrub savannahs are characterized by a grass layer at least 80 cm high, while woody species are seldom more than 5 m high and are scattered throughout the grass cover.

Riparian formations are extensions of the semi-deciduous forests along rivers in the savannahs. Species associations vary and include *Terminalia ivorensis*, *Triplochiton scleroxylon*, *Khaya senegalensis* and *Parinari excelsa*.

Utilization patterns

The only source of information available on the size and evolution of woodland and savannah surfaces is *Forest resources of tropical Africa* (FAO/UNEP, 1981). In this technical report, the total estimated surface of open broad-leaved formations was 84 million ha in 1980, or 28 percent of the total area of the Sudano-Sahelian zone. It is imperative to learn how much is left, as deforestation has been accelerating ever since.

The main utilization of woodlands and savannahs is that of a reserve of arable lands with low human pressure which serves as a safety valve in face of the increase of food production, without intensifying production methods. An example of this is the grain plan, recently proposed to the Burkina Faso Government, which notes that in the year 2005 the demand for local grain will increase to 750 000 tonnes of gross production. This will entail the clearing of 600 000 ha with an assumed yield of 700 kg per hectare or of 900 000 ha with a yield of 600 kg per hectare. Real technological innovations are very limited and productivity increases over the past 15 years have not exceeded 2 percent per year. Average long-term production growth has remained below population growth. In conclusion, the development of rainfed grain production depends on the expansion of the cultivated areas (SEDES-CEDRAT S.A., 1990). However, to these planned "expansions", other components should be added which cannot be planned. These are the regular, unobtrusive, continuous migrations resulting from soil depletion caused by single-crop farming with insufficient inputs of organic and mineral fertilizers as well as insufficient fallow because of the saturation of space in village areas. This migration process becomes chaotic, uncontrollable and turns into mass migration in times of drought, as in 1968, 1973-1974 and 1983-1984. Hence the appearance of the clearing fronts, the systematic growing and rapid shrinking of forest formations which mark the recent evolution of the landscape in the Sudano-Sahelian countries.

The second most important form of utilization of forest formations after that of farmland reserves is harvesting for fuelwood production. The populations of the Sudano-Sahelian zone use very little oil and electricity. On the other hand, their annual fuelwood consumption is approximately 0.6 m^3 per caput, corresponding to an average of 90 percent of the total energy used, except for Senegal and Mauritania where fuelwood consumption falls, respectively, to 60 and 69 percent (Giri, 1983).

Fuelwood production comes mainly from the wood left over from clearing operations and which farmers are willing to gather for their own use and for sale when economically accessible markets are available, in order to cover the clearing cost. Conversely, on the outskirts of larger urban centres, the production of fuelwood leaves rings of land, sometimes extending beyond a 50 km radius, stripped of woody vegetation. In some areas, these sources of production are supplemented by the collection of dead wood, a category which includes both tree stands withered by drought and trees that die every year through forest fires. The pressure on forest formations through uncontrolled clearing and fuelwood harvesting is so excessive that it can be considered much higher than their natural regeneration capacity.

In this connection, it is significant that in the tree savannahs, which account for most of the region's areas that are still forested, the total growing stock seldom exceeds 15 m^3 per hectare. The recurrent assault of forest fires has reduced the annual growth rate of tree savannahs to less than 1 m^3 per hectare. This observation is shared by the Organisation for Economic Cooperation and Development (OECD) which, in establishing a tentative scenario, asserts that: the Sahel manages to survive reasonably well, with no real growth and at the cost of a strong increase in its external dependency as well as a fairly rapid erosion of its natural capital.

Nevertheless, in the analysis of the region's prospects it is estimated that the replacement of wood by imported fuels for domestic use is excluded. Agriculture must supply not only food and the bulk of the foreign exchange needed to finance imports but also part of the energy required by the Sudano-Sahelian region (OECD, 1988).

Cattle production, although not proportionate to the size of the preceding forms of utilization of forest formations, ranks third in importance. The extension of farmlands inexorably reduces the space available for traditional cattle farming. Transhumance becomes more and more difficult and the movements of herds during the wintering season is the source of sometimes deadly conflicts between farmers and shepherds. The latter, although limited by the presence of trypanosomiasis, are forced to shelter their herds in the forests and engage in tree delimbing in order to reach the higher fodder. Hence, the emergence of various silvopastoral management practices, whose technical content has had mixed success; it often does not go beyond merely destroying the tree savannah and its replacement by a grass savannah dotted with patches of desertification.

Among the forms of forest formation utilization one should also mention the wood processing industry and the traditional use of forests by rural populations. The wood processing industry remains confined to sawnwood, and the processing capacities that are very scarce in terms of volume seem not to have exceeded 12 percent of growth in the past decade (FAO/UNEP, 1981). On the other hand, the traditional uses of the forest as a source of medicines, fruits and proteins supplied by game are becoming difficult, given the disappearance of forest formations.

The assessment of these uses underlines the crucial role of forest in the survival of the Sudano-Sahelian populations, intensifying the concern over the rupture of the ecological balances which already threatens 25 million people through deforestation, desertification and migration. The village authorities used to preserve the natural environment with rules which have more or less disappeared with the disruption of traditional society. New rules, suited to the total change in demographic and economic conditions, are necessary. The management of natural forests, a branch of forestry that studies forest sciences and techniques in their relation to administrative, legislative, economic and social principles (Metro, 1975), can usefully contribute to the shaping of new balances in the rural world.

MANAGEMENT PRACTICES

Management of natural forests

A few years ago, the only countries of the Sudano-Sahelian zone that could boast the use of management practices for their natural forests, in the sense of a clear definition of production targets and the actions to attain them, were Ghana and the Sudan. In fact, these countries had long-standing harvesting rules, often accompanied by forest-tending methods aimed at regenerating forests by enriching them if possible (FAO/UNEP, 1981). Today most countries are starting their own experiences in the field and adding to it the new dimension of people's participation. Forest management, despite difficulties arising from the absence of a specialized silviculture, the complexity of landownership and the social and economic organization of the rural populations, is beginning to be viewed by policy-makers and financiers as a viable alternative. Forest management is regarded more and more as a tool that can contribute efficiently for a few more decades to answering the need for domestic energy; creating rural jobs; regulating the use of natural resources; quickening the pace of changes in agricultural production methods; setting up stable forms of coexistence with animal production; and preserving a natural environment intrinsically linked to African culture.

The experience of Burkina Faso

One of the most progressive projects dealing with the management of natural forests in the Sudano-Sahelian area was undertaken by Burkina Faso in 1986. Financed by UNDP and implemented by FAO under the supervision of the Ministry of Environment and Tourism, it was completed in 1993. The expected results were: the management of 200 000 ha of village areas and the comanagement of 100 000 ha of forest formations with the participation of the local farmers and the regular production of 50 000 m^3 of fuelwood per year, starting from 1993.

The management practices followed by the Burkina Faso project include the following:

- Effective and voluntary participation of the rural population organized in village forest management groups.
- The conservation and enrichment of forest formations, especially those where growing stock exceeds 10 m^3 per year.
- The creation of economically self-sufficient forest industries, comanaged by the farmers and the forest services.
- Close cooperation with the private sector responsible for transporting fuelwood and its marketing to customers.
- Use of the economic and social dynamics triggered by forest management to support the organization of livestock breeding and agriculture, including land use, in the village areas.

The management plan aims at producing fuelwood to supply the town of Ouagadougou. It divides the forest formations into management units of different sizes ranging from 2 000 to 4 000 ha in order to set up a block of plots with a 15-year rotation; evaluates the forest potential; sets harvesting regulations which limit wood extraction to 50 percent of the growing stock; establishes enrichment planting for the plots destined for harvesting; and ensures maintenance of the forest roads and forest fire prevention and control.

The management model set up by the Burkina Faso project is divided into two clearly defined phases. The first formulates the management and administration plan, including training village instructors and management officers, and follows up the first year's implementation of the management plan. This phase is financed by non-forest resources and is carried out by the project team with the farmers' participation.

The second phase concerns the comanagement of the forest production business responsible for applying the management plan. The business is run by a management council consisting of representatives of the village forest management groups, the forest services and the provincial administration. Management costs are covered by income from the forest production itself, based on an amount deducted from the price of each stere sold. This is the management fund.

Description of the intervention area. The project intervention area lies south of Ouagadougou in the north Sudanese climatic zone with rainfall ranging from 700 to 900 mm. Forest formations are mainly of the tree savannah type, including *Butyrospermum paradoxa* var. *parkii*, *Detarium macrocarpum*, *Terminalia* sp. and *Anogeissus leiocarpa* with an extensive grass layer. Wooded savannahs are present in patches including *Burkea africana*, *Isoberlinia doka* and *Daniellia oliveri*. Rivers and lowlands have riparian formations with a predominance of *Khaya senegalensis*, *Pterocarpus erınaceus*, *Burkea africana* and *Parinari excelsa*.

According to Burkina Faso land legislation, all lands falling within the boundaries of the national territory form part of the National Forest Estate belonging to the state (Government of Burkina Faso, 1991). The project intervention area is divided between the 30 000 ha of the gazetted forest and the 70 000 ha of the non-gazetted forests. For customary authorities, all land in village areas belongs to the indigenous populations. Arbitration of conflicts and the attribution of land to migrant applicants are assured by the village and land chiefs. The migrant beneficiaries, however, cannot appropriate it even after prolonged use, nor undertake certain activities without the owner's previous authorization. The loan of land subject to mutual aid and hospitality obligations is not binding on the beneficiary (Nougtara, 1991). The population comprises four different ethnic groups: the indigenous Gourounsis (30 percent), the Mossis (57 percent), the Peuhls (10 percent) and the Wallas (3 percent) (Douamba, 1991).

Despite the main roads that cross it from north to south, the project intervention zone remains largely landlocked because of the absence of cross-country links. The population is settled in about 100 villages of varying sizes. In 1985, 84 000 peopled lived in these villages. Assuming an annual population growth rate for the area of 5 percent, there could be about 120 000 inhabitants today.

The main economic activity is agriculture, essentially on a subsistence level, with a marginal participation in cash crops; the extensive and nomadic livestock production practised around the area includes about 30 000 head of cattle and almost as many small ruminants. State services are limited to insufficient pnmary schools, health centres and extension services. Trade seems to be concentrated in the weekly village markets, with intervillage exchanges as their main feature.

The present size and prospects of the fuelwood market in Ouagadougou are determined by the assumed population growth and the maintenance of the consumption level, evaluated for 1987 at 0.66 kg per person per day. Based on these figures in 1990, the estimated annual demand for fuelwood was about 240 000 m^3 while, in 2000, it is projected to rise to 600 000 m^3 (Zida, 1991). This means that the fuelwood market is assured even if it exceeds the annual production of the forest formations that supply the town of Ouagadougou, and is estimated to be 530 000 m^3 per year (World Bank/UNDP, 1990).

The management plan formulation phase. The management plan formulation phase included the following activities:

- *Setting up a soil map at a scale of 1:200 000:* the first phase, aimed at identifying blocks suited to management, was carried out using Landsat TM images at a scale of 1:200 000. The end of the rainy season was chosen to record the scenes in order to obtain maximum vegetation cover of the soil. Physical maps (at 1:200 000) of Burkina Faso's Geographic Institute were used as a planimetric background to prepare monochromatic mapping (Ribot, 1991).
- *Identifying the villages concerned and checking their potentialities:* this involved low flights followed by ground surveys based on pre-established procedures.
- *Using information campaigns:* an information campaign addressed the administrative and village authorities on the objectives of forest formation development.
- *Compiling a map of land occupation at a scale of 1:20 000:* the blocks selected jointly with the village authorities are subjected to a photographic coverage at 1:20 000. Photo interpretation and mapping activities stress the different types of forest formations, human occupancy and river and road networks.
- *Organizing groups:* instructors organize village meetings with all wishing to participate in order to describe the planned activities, advantages and constraints. Decisions concerning forest management groups are the sole responsibility of the villagers.
- *Training:* management groups select one forestry instructor for every 20 people. The ten-week training course comprises three sessions: logging, silviculture and forest fire protection.
- *Establishing management units and plots:* the management units are established according to the estimated forest potential, inter-village preferences, number of members of the groups and available access routes. The plot block is determined by the area of the management unit and the number of years of the rotation adopted.

- *Evaluating forest potential:* this includes establishing the dendrometric and ecological parameters that should determine the final form of the management and administration plan.
- *Compiling a comanagement contract:* the comanagement contract is a forest resources usufruct agreement conditioned by the management and administration plan.
- *Formulating the management and administration plan:* this is a document that summarizes the cartographic, legal and socio-economic data of the forest and specifies the management targets. Intervention methods concern mainly rotation time, the harvesting system, the silvicultural methods to be applied in order to ensure regeneration of the formations and the form and intensity of the activities associated with forest management, including agriculture and cattle production.

Comanagement. Comanagement is implemented through a wood production firm, regulated by the management and the administration plan. Farmers, who are organized in forestry management groups and joined in a group union, participate at all the decision-making levels.

Constraints

The progress achieved by the Burkina Faso project in creating a natural forest management model with farmers' participation has enabled it to identify the limits of technical expertise and the magnitude of socio-economic constraints.

Technically, the main problems are few: forestry knowledge, control of forest fires, length of the rotations and inventory methods suited to the heterogeneous species and varying ages of the forest formations in the Sudano-Sahelian zone.

However, the main constraints to implementing sustainable management of forest formations stem from legal and socio-economic factors. On the one hand, there are the complex relationships and contradictions between land legislation and customary rights, in particular concerning landownership and usufruct of forest resources; on the other hand, there are problems of establishing new forms of rural land organization and utilization of natural resources in place of the present agricultural and livestock production methods.

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Sustainable management of plantation forest in the tropics and subtropics

E. Campinhos Jr

This paper discusses the necessity for using the best possible technology for establishing and growing high-yielding forest plantations for volume and quality in the tropics and subtropics.

After describing the Brazilian forestry situation and wood consumption and production in Brazil, the paper cites a successful Brazilian example of forestry plantation in a tropical region: Aracruz Cellulose, a private company which is located in Aracruz in Espirito Santo state. The company produces 1 025 tonnes of bleached cellulose annually from its eucalyptus plantations, with sustainable management as the main goal. Company practices include the use of appropriate genetic material for tree improvement, soil conservation, pest control, improved logging practices and equipment, research into residue use and the conservation of native flora and fauna samples.

Introduction

Every year, forests become increasingly important to rural communities for the provision of goods and services. To increase wood supplies for energy, construction, fibre and other uses, new forests are being established with new quality and productivity concepts.

Environmentally, forest planting is imperative: it protects and restores the environment; supplies energy; reduces the pressure to clear tropical and subtropical forests; sequesters carbon released into the atmosphere; and is an

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income source for farmers. Forest plantations offer attractive returns when fast-growing species for tropical and subtropical regions are used, for instance some *Eucalyptus* and *Pinus* species. The use of these versatile species is frequently opposed, owing to negative myths, but such high-value species cannot be easily substituted.

Technological forest development for tropical and subtropical regions has been rapid over the last two decades. Current techniques establish forest plantations with minimum waste and maximum productivity.

This paper outlines the Brazilian forestry situation and illustrates the results of Aracruz Cellulose's forestry and industrial activities in developing and adapting technologies, respecting the environment, creating good working conditions and in striving for sustainable development.

Brazilian forestry

In Brazil, there are two types of forest: tropical and subtropical. Brazilian colonization, which occurred more intensively in the central-southern region of the country, meant that subtropical forests rapidly gave way to agriculture. *Araucaria angustifolia* (Brazilian pine) is one of the most valuable and representative species from that region. Currently, good specimens of that species can only be observed in forest reserves because the best trees have gone to the sawmill and the forests have made way for grain plantations. Owing to Brazilian pine's economic importance, a federal government agency, the Instituto Nacional do Pinho (National Pine Institute), was created in the 1940s to re-establish the forests.

Accelerated population growth, the need for new agricultural lands and the use of low-technology agriculture all generated strong pressure on forests, and forests in the northern, western and eastern regions were reduced to vast degraded and unproductive areas. New forests were felled for hardwood exports, this time in the Atlantic and Amazonian tropical areas. Only the best parts of the tree (about 30 percent) of a few hundred species were cut and used; the balance was burned.

Today in Brazil, the situation is changing. There is a general concern about and awareness of forests' beneficial effects and their rational use in sustainable development without environmental degradation.

The current Brazilian forestry situation

The federal and several state governments are strictly regulating native forest cutting in an attempt to preserve what remains. However, they cannot completely halt forest cutting for community needs.

As forests are renewable resources, they should be utilized properly, with mature trees being felled before they die. However, no conclusive experience exists for this kind of forest management. There is research into indigenous forest management, especially for tropical forests, but results are slow to arrive since forests grow slowly.

The increasing difficulty for markets to offer wood, in addition to the consequent price increases, makes farmers plant fast-growing tree species. For example, *Eucalyptus* sp. and *Pinus* sp. are being planted both in the tropical and subtropical regions, and their products are marketable. The only constraint is that these are not habitual wood species since indigenous woods were used traditionally. The government has therefore encouraged the establishment of these fast-growing trees: in 1967, fiscal incentives for forest plantations were created in Brazil. This move generated the planting of 6 252 000 ha up to 1986, mainly of eucalypts and pines. In 1989, these incentives stopped, although some Brazilian states offer financing through their development banks.

Some of the plantations were unsatisfactory, through a lack of knowledge of the forestry techniques suitable for each region and for selected species. This led to the creation of research institutes and forestry schools. Many industries were established for the new forests, as in the case of Aracruz Florestal.

Wood consumption and production in Brazil

The main uses for wood in Brazil, both indigenous and planted forests, are:

- *Charcoal*. Charcoal production began in the second half of the nineteenth century, using only wood coal from indigenous forests. In 1987, total charcoal production was about 34 million m^3, with 80 percent of this from indigenous forests.
- *Pulp and paper*. From 1970 until 1987, pulp and paper production increased by 10.6 percent annually, reaching 3.8 million tonnes in 1988. All wood is from planted forest: 67 percent is hardwood (eucalypts) and 33 percent softwood (Brazilian pine etc.).
- *Lumber*. The fiscal incentives for reforestation are already making an impact: pine forests planted at the beginning of 1967 have already placed about 3 million m^3 of wood per year on the market.
- *Indigenous wood veneer*. Approximately *500 000* m^3 of plywood are produced per year.

Nevertheless, there is a considerable gap between the amount of wood produced from planted forests and the increasing demand for its products. For the year 1987/88, the difference was about 182 million m^3.

The outlook is very similar in most developing tropical countries. These countries have great potential for establishing industrial and high productivity forests: the climate is favourable, and human resources, technology and seeds are available.

Pulp mills do not use indigenous wood. They use wood produced from planted forests with improved species suited to fibre production. The plantings are made in an orderly way allowing rational management aimed at a sustainable yield. These (plantation) forests are effectively a short-cycle tree culture or lignoculture and are called forests more because of their size than their composition.

The need to produce homogeneous and good-quality wood for pulp production makes each industry plant its own forests and also encourages nearby farmers to dedicate themselves to the tree plantation, thereby becoming a partner in timber production.

A Brazilian example of a tropical forestry plantation: Aracruz

Aracruz Cellulose, a private Brazilian group, is located in the Aracruz municipality, 65 km from Vitoria, capital of Espirito Santo state. The company follows an integrated concept, consisting of eucalyptus forests, two pulp mills, an electrochemical plant, a port and a residential town where some of its 7 500 employees live. Aracruz Cellulose, the holding company of the group, is an enterprise with more than US$2 billion in capital value.

The company's pulp mills can produce 1 025 000 tonnes of bleached market pulp per year, exporting 80 percent of its production to about 20 countries.

Aracruz Florestal is responsible for the silvicultural activities of the Aracruz group, including forestry research, plantations, environmental protection and logging and transportation of eucalyptus wood to the pulp mills. In the overall business, Aracruz Florestal has increased results in pulp productivity in line with the development of worldwide pioneering techniques and methods.

Starting in 1967, Aracruz established its forests in the northern coastal region of Espirito Santo state and in the south of Bahia state, concentrating the Selected sites in three regions, with an elevation of up to 100 m, an annual rainfall of about 1 400 mm and an annual average temperature of about 24°C. The total land area is 203 226 ha, of which 131 322 ha are covered by eucalyptus plantations and 71 904 ha are occupied by the remaining indigenous forests and service areas.

Owing to the lack of experience with eucalyptus plantations in the region and the absence of improved seeds adapted to the local environmental conditions, an annual mean increment of 28 m^3 in the first plantations was obtained. Acquiring selected material for local conditions to guarantee a better production in the second generation has represented a real challenge.

A research programme was essential for conducting the forestry project. Starting in 1971, eucalyptus species and provenances and progenies from Australia and Indonesia were introduced. This programme aimed at producing improved genetic material adapted to local conditions. On average, 12 years were required to reach the first stage of superior seeds.

Aracruz built a research centre and arranged for seed collection in Australia and Indonesia. At the same time, to accelerate the use of good genetic material, studies were carried out to develop a method for vegetative propagation by rooted cuttings or clones.

Selection of better trees in the planted forests and company research made it possible to identify the spontaneous hybrids adapted to the region's environmental conditions, which resisted pests and diseases better and yielded higher volumes (45 m^3 per hectare per year) and more pulp (> 50 percent). Some synthetic hybrids (*Eucalyptus grandis* x *E. urophylla*) reach quite high increments (70 m^3 per hectare per year) when the clone and soil interact well.

Results achieved in this clonal experimentation phase showed highly compensatory productivity and a wood of homogeneous characteristic clones; thus, in 1979 the company chose to replace plantations gradually, using seeds by clonal plantations.

In 1986, harvesting of the first clonal plantations confirmed research expectations: wood consumption at the plant decreased from 4.87 m^3 to 4.26 m^3 per tonne of pulp, resulting in significant advantages in product quality and production and optimizing plant equipment usage. Clonal plantations also present advantages of about 22 percent in harvesting and logging operations, through their tree uniformity, high survival and branch-free stems, which give lower costs.

Because of its pioneering work in developing and adapting clonal plantations, in 1984 Aracruz won international recognition with the prestigious Marcus Wallenberg Prize.

Aracruz Florestal sustainable management policies and practice

There had been previous exploitation of the vegetative cover in the areas where Aracruz wanted to install its pulp mills, causing some limitations to company activities. Formerly occupied by exuberant tropical forest, these areas were covered by weeds and bush and their soils of inherently low fertility were further depleted.

To overcome this, the company developed several actions to achieve high productivity and quality in its wood production for cellulose. With sustainable management as the main goal, these actions have evolved over the years and can be summarized as follows:

Genetic material. Species, origins and progenies of eucalyptus adapted to local conditions were selected through tests evaluating the interaction of genetic material with the prevailing environment in company areas. This procedure significantly increases productivity and, at the same time, minimizes environmental impacts by introducing exotic species.

Soil conservation.

- After wood cutting, forestry residues (leaves and branches) are incorporated without burning and without turning the soil excessively. This procedure aims at reducing the loss of nutrients and organic matter as well as the risk of erosion.
- Soil fertility, biomass production and the exportation of nutrients are monitored after wood cutting. The data obtained, together with those from research, enable fertilization to be carried out, thus preventing nutrient depletion in the soil and maintaining and/or increasing forestry productivity.
- Forests bordering rivers and lakes are maintained and enriched in order to protect water supplies and maintain biodiversity.

Biodiversity.

- The remaining natural vegetation integrated in forestry plantations is maintained and enriched, resulting in 1 ha of natural vegetation for every 2.4 ha of eucalyptus plantation.
- With habitat maintenance in company areas, 156 bird species (25 of which combat eucalyptus pests), 36 mammal species and 3 000 insect species were identified.

Pest control. Preventive pest control is based on a computerized system for detecting primary focus, which periodically monitors all company areas. The efficiency of the system means that intervention is necessary in less than 0.02 percent of cases.

The remaining cases return to equilibrium by natural biodiversity. If treatment measures are needed, biological control is preferred.

Logging.

- Improved tools were developed for manual cutting.
- For the first time in Brazil, the company has introduced cutting using a harvester.

Forestry equipment.

- In 1984, Aracruz introduced units for on-road transportation. Together with a vehicle manufacturing company, the company is currently developing a new three-wheel bidirectional semi-truck trailer. This unit is very stable and can ascend sloping roads, thereby increasing the loading capacity by 19 percent.
- Aracruz has introduced and adapted a more modern, economic and ergonomic forestry tractor family, which has resulted in better off-road wood transportation.

A series of research and operational tests are being carried out, aimed at maintaining the evolution of sustainable forestry management. Scientific knowledge and research orientation are being brought from national and international universities and research institutes by Aracruz through a close cooperation and exchange programme.

Research. Research activities in progress or being initiated emphasize:

Leguminosae. Tests are being made with some tropical fodder and alimentary Leguminosae associated with eucalyptus plantations, aimed at biodiversity, culture treatment (inhibiting or reducing competition from undesirable weeds) and nitrogen and organic material fixation. Some species have shown potential to produce biomass and inhibit weeds with the first results.

Forestry management units. These units will be established using data from soil surveys, soil preparation and fertilization monitoring and research, determining specific management for different environmental conditions. Factors considered include:

- genetic material
- site preparation and fertilization
- weed control
- road maintenance
- soil conservation of planted areas
- environmental planning

Utilization of residues. Eucalyptus bark is being tested as a growth medium for compost utilization in forest nurseries. Bark is also being used successfully for recuperating degraded areas.

Ash from auxiliary boilers – with a large amount of calcium, magnesium and potassium – is being used in operational tests to complement the fertilization of eucalyptus plantations.

Preservation of native flora. Experiments are being performed to define ideal sustainable management of different forestry fragments. By forming a seed bank of local indigenous arboreous species, Aracruz intends to identify those species that can produce energy, pulp, saw mill products, etc., and thus use them in silvicultural research and possibly in reforestation projects.

Preservation of native fauna. Quantitative and qualitative studies on the bio-ecological and support capacity in company areas aim at reintroducing some fauna species in danger of extinction or of not settling again in the preservation areas.

Because of these and other company measures on environmental questions since it began activity, it was possible to sign the Business Charter for Sustainable Development in Rotterdam in April 1991. This document, written by the International Chamber of Commerce, with United Nations support, establishes 16 criteria for environmental protection and recovery to be attained and verified by industries. Among the 150 signatory companies, Aracruz was the first to represent Brazil, setting an example and opening the way for other companies.

It is important to emphasize that, when this global document was signed, Aracruz had already fulfilled many of the indexes and requirements and should meet all remaining criteria very soon.

Conclusions and recommendations

- This paper describes a successful forestry business in a tropical region based on eucalyptus forest plantations, supplying a pulp mill that has a capacity of 1 025 000 tonne bleached pulp per year.
- Tropical and subtropical regions offer good opportunities for high-quality and fast-growing forestry plantations, with competitive costs. Land and labour are available. Government representatives should understand this opportunity and develop a realistic forestry policy that incorporates reforestation incentives.
- Policy for exchanging developed technologies and for evolving them and adapting them to local conditions, has created a tremendous and beneficial synergy among technicians, resulting in effort and cost re-

ductions. This was the case with Aracruz, after establishing relationships with forestry technicians of public and private companies in many countries.

- Technology developments for reforestation in tropical and subtropical countries create opportunities for establishing new projects and adaptations to local conditions.
- It is necessary to respect the environment, to preserve it and restore it.
- A key point in a reforestation programme is to identify genetic material sources. The growth of selected genetic material should be quantified in each region.
- Forests can act as "carbon sinks", contributing to the capture of excess carbon dioxide in the atmosphere. Tree plantations are at once ecologically appropriate, economically profitable and socially acceptable.

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Sustainable management for non-wood forest products in the tropics and subtropics

G.E. Wickens

This paper describes the sustainable management of forests in the tropics and subtropics for non-wood forest products. Sustainable management for non-wood products means balancing optimal productivity and controlling ecological change so that environmental equilibriums are maintained. Management requirements will vary according to site, species and the needs of the local communities and the government, etc. Other subjects covered include the possibility of combining sustainable management for non-wood products with that for timber production; the use of fire in sustainable management; rotational coppicing to maintain sustained yields of fuelwood, of wood for poles, etc.; improving non-wood products through natural variation, vegetative propagation and selection for desirable traits; and rotational cropping, agroforestry and shifting cultivation. Finally, the paper provides an example of the management ramifications required for the sustained productivity and conservation of non-wood products in the 77 000 km^2 Aïr and Ténére National Nature Reserve in the Niger.

Introduction

The distinction between wood and non-wood products is ill-defined and variously interpreted by different organizations and nations. In the present context, "wood" refers to roundwood, sawn timber, wood-based panels, wood chips and pulp, and it often involves commercial enterprises.

The term "forest", as it is used here, approaches its original meaning as an

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unenclosed woodland or open, mainly treeless area, reserved for hunting and embracing all the natural ecosystems where trees and shrubs form a significant component. Thus, "forests" range from evergreen rain forests to desert. However, in the latter, trees and shrubs are confined primarily to oases and waterways.

"Non-wood forest products" refers here to all the biological material (other than wood products defined above) that may be extracted from natural ecosystems and managed plantations and that can be utilized within the household, be marketed or have social, cultural or religious significance. Such products include: plants used for food, beverages, forage, fuel, medicine, fibres and biochemicals; and animals, birds and fish used for food, fur and feathers; as well as their products such as honey, lac and silk. Ecosystem use for recreation, nature reserves and catchment management is regarded as forest services. Forage according to FAO usage (Ibrahim in FAO, 1975), includes "all browse and herbaceous food that is available to livestock or game animals". Thus, forage includes non-wood forest products that sustain such animal populations.

Management for non-wood forest products

Non-wood forest products are an integral part of the survival and development strategy for the continuing well-being of man, livestock and native flora and fauna. Often considered a forest by-product, unfortunately the potential economic value, either monetary or in terms of utilization (e.g. wild foods, browse, bushmeat), is often unknown or unappreciated by managers. Forest management can no longer be concerned solely with timber production. It is also necessary to consider environmental impact studies and the effect of timber production on the well-being of local people in terms of floral, faunal and medical ecology, ethnobiology, sociology, etc.

The role of forest managers is to maintain or increase the productivity of forest resources while protecting them from overexploitation. The aim is to provide essential products and services while simultaneously allowing for the needs of the local rural people. For non-wood forest products the challenge is therefore to assist "development" while simultaneously promoting the continued and possibly increased sustainable utilization of such products (Wickens, 1991).

There is a wide variation in management requirements associated with non-wood forest products, reflecting the varied environmental requirements and habitats of the species concerned. Furthermore, other management requirements include such diverse interests as the local communities acting either as individuals or collectively, external entrepreneurs acting independently of the local community, and local or national government agencies with interests and policies that may or may not reflect the well-being of the local community. Thus, there can be no single solution to the management requirements for non-wood forest products.

Both natural and planted forests are a rich source of non-wood forest products. Unfortunately, harvesting their wild products is sometimes inefficient and done using destructive methods. The potential markets for some of these products has resulted in their replacement by cheaper, synthetic products. The need for a constant supply, as in the case of pharmaceutical products, has also led to synthesization. The few products that cannot be readily synthesized, such as natural rubber, have been taken into agricultural production or are undergoing domestication, for instance rattan (Poore, 1989). Thus, entrepreneurs and government policy-makers need to consider supply, demand and global economics affecting the more commercially viable non-wood forest products, which may or may not concern the rural user.

At one extreme, the natural resources may be managed and maintained by the community without any need for government intervention: for example, the so-called "primitive" forest-dwelling communities of Amazonia are very adept at utilizing and conserving local resources. The Kayapo Amerindians from Gorotire village in southern Pará state, Brazil, utilize more than 98 percent of the 120 species identified from clumps of woody vegetation (*apêtê*) within the local scrub savannah (*campo cerrado*). Furthermore, the Kayapo prepare suitable planting media from litter and termite and ant nests, and take them to the *apêtê* where selected useful wild species are planted. Some desirable species may even be brought from considerable distances (Anderson and Posey, 1989).

Similarly, the swidden cultivation areas of the Ka'opor Amerindians are cropped and rotationally abandoned so as to create a succession of diverse habitats to maintain both flora and fauna. Thus, the secondary forest is being manipulated for the sustainable production of both floral and faunal resources by utilizing the various vegetation zones in different stages of recovery (Balée and Gély, 1989). Such community-based management systems challenge governments to ensure that such sustainable community forestry systems continue to survive as the communities are exposed to the outside world.

The integration of non-wood forest products with timber production can provide both local benefits and make timber extraction more environmentally sustainable and economically feasible. Thus, Caldecott (1988), in his proposal for a review of forest policy in Sarawak, suggested increasing production of non-wood products and introducing longer felling cycles and lower harvesting intensities for timber. Revenue loss from the lower timber production is offset by the increased revenue from non-wood forest products. An example is the Yapo National Forest in southern Côte d'Ivoire, consisting of both plantations and natural forest. The 1987 revenue from the non-timber products totalled US$26 000 and helped defray management costs (Falconer, 1990).

Unfortunately, there is still insufficient information on how to manage forests to yield a diversity of products. Referring specifically to West Africa, Falconer (FAO, 1990) observed that there are no examples of community forest activities designed to enhance pre-existing forest resources. However, quite often it is difficult to distinguish between such community forest activities and conservation projects. Cameroon's declaration of Korup as a National Rainforest Park in 1987 was primarily intended to conserve 125 000 ha of rain forest in an age when the world's tropical forests are disappearing at the rate of 40 ha per minute. By establishing a buffer zone around Kirup as well as agroforestry schemes, the project aims at increasing the productivity of the 30 000 small-scale farmers living in the region while safeguarding the future of the rain forest in the heart of the national park.

The use of fire

In use since antiquity, fire is the oldest of land management practices, and is practised throughout the tropical and subtropical woodland, scrubland and grassland ecosystems (Warmington, 1964; West, 1965). Fire may be used by the pastoralist as a range management tool to control plant succession; encourage fresh grass growth early in the growing season; destroy undesirable plants and insect pests; and reduce the fuel load and potential risk of accidental fires (Edwards, 1984). Fire may also be used to clear or clean lands for cultivation.

An understanding of the principles of fire behaviour and its effect on the flora and fauna is essential for its use as a management tool for sustainable production.

The impact of fire on flora and fauna depends upon the frequency, intensity and height at which heat energy is released. The time of the year is also important. Thus, the burning of grasslands at the end of the rainy season can be harmful, since many of the perennial species are still translocating food reserves from the leaves for storage in the roots. The fire stimulates the grasses to produce fresh growth at the expense of the inadequate food reserves stored in the root system. The weakened species are then replaced by more fire-tolerant and generally less palatable perennials or even annuals. The bared soil may also suffer erosion (Scott, 1955).

Fire may also be used to control bush encroachment and to maintain a favourable balance between woody and grass species' competition for moisture and nutrients and the livestock's requirement for herbage, browse and shade. A late burn, before the grasses have started to produce new growth but sufficiently late in the season to leave the bared soil exposed for the shortest possible time, can be effective in controlling bush encroachment (West, 1955). The frequency of such burns should be such that undesirable trees and shrubs from either seed or coppice regrowth do not mature sufficiently to produce seed or become resistant to fire (Kruger, 1984; Mentis and Tainton, 1984).

The impact of fire on fauna survival is poorly documented. Flightless insects, eggs and immature mammals may be destroyed whereas birds and adult mammals can escape. Whether the faunal population returns depends on the environmental changes resulting from the fire. Overly frequent fires may result in long-lasting or even permanent faunal changes (Bigalke and Willan, 1984).

Much of the above information is based on experience in southern Africa and is not necessarily applicable to other regions of the world where different ecological and climatological conditions prevail. Indeed, the use of fire and its effects within the biomass of South Africa, as described in Booysen and Tainton (1984), are sufficiently variable to exclude the recommendation of one single management methodology.

The following examples from Australia and Central America illustrate the use of fire to manipulate non-wood forest products. Prior to European contact, the Alyawara aborigines of Central Australia survived by hunting and gathering; their highly variable pattern of movement depended on food and water distribution, a pattern determined by the climate and a knowledge of the ecology of both flora and fauna. *One reason for the* now limited distribution of formerly important food plants is attributed by the Alyawara to the government's policy of discouraging fire use. Fire was used by the Alyawara to drive game from cover, to clear ground for hunting and plant collecting, or for camp sites. The area burnt rarely exceeded 1 km^2; nevertheless it had an important impact on the abundance and distribution of those edible plants that favoured disturbed habitats and it created patchy habitats where animals could find fresh forage close to unburnt cover. Although it is unclear whether fire was deliberately used to promote environmental change, the Alyawara certainly recognized its effect (O'Connell, Latz and Barnett, 1983).

A more deliberate and localized example of the use of fire to influence the productivity of a single species is in the Jaumave region of the Sierra Madre Oriental in Mexico. Here, the campesinos use the rhizomatous, perennial bushgrass, zacaton (*Sporobolus giganteus*) for thatching. During winter, the zacaton stands are burnt to destroy insect pests, eliminate competitive grasses and shrubs and destroy any accumulation of dead material. The burning also creates higher and thicker culms and stimulates the rhizomes to expand the stands of zacaton (Anderson, 1991).

Coppice regrowth

Rotational coppicing of a number of trees and shrubs (*Azadirachta* sp., *Eucalyptus* sp., *Ziziphus* sp., etc.) can also be used for maintaining sustainable yields of fuelwood, straight poles for fencing, walls, roof timbers, tool handles, etc. and also for prolonging species life. The cutting of reeds and reed grasses, such as *Phragmites australis* and *Arundo donax*, can stimulate further rhizome growth (Anderson, 1991).

Improvement of non-wood forest products

There is an enormous potential for developing non-wood forest products, especially in the developing countries. Wild foods, for example, can contribute substantially towards fulfilling dietary needs, especially during seasons of the year when conventional staples are unavailable. For example, in West Africa, the African pear (*Dacryodes edulis*) matures during the "hungry season" when the agricultural crops have been planted but are not yet ready for harvest (Okafor, 1991).

Ogden (1990) and Falconer (1990) recognize the nutritional benefits of wild forest foods as sources of protein, minerals and vitamins. The dietary value of such wild foods has also been observed among the desert peoples, including the Australian aborigines, Ethiopian Jews and the Amerindians of Mexico and the southwestern United States.

Like industrial timber trees, natural variation within non-industrial multipurpose trees and shrubs offers similar management opportunities for conserving, developing and utilizing plant resources (Okafor, 1991; Venkatesh, 1988). Among the Nigerian wild fruit-tree resources, the recognition of taxonomic varieties with significant differences in the phenology of flowering, fruiting and leaf flush has led to the possibility of deliberately extending the period of fruit and vegetable availability, increasing productivity and selecting the desired pattern and yield season (Okafor, 1978; 1991). Such fruit-trees include *Dacryodes edulis*, *Irvingia gabonensis* and *Terculia africana* ssp. *africana* (Okafor, 1977; 1980; 1991). For example, the fruit availability of *Irvingia gabonensis* can be significantly extended by using var. *gabonensis* and var. *excelsa* which fruit in the rainy and dry seasons, respectively.

The successful methods of vegetative propagation used include budding, stem cuttings and truncheons. Different varieties may require different management objectives and practices. For example, for food production Okafor (1980) recommends using the budded plants of the large-fruited *Treculia africana* var. *africana* to reduce bole length and height of fruit set, while the smaller-fruited var. *mollis* and var. *inversa*, which are better suited for pulp production, can be reared from unbudded fruits.

Agroforestry and rotational cropping

Von Maydell *et al.* (1982) defines agroforestry as a new term for the old practice of growing woody plants with agricultural crops and/or livestock together on the same land. It is the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals, either in some form of spatial mixture or in sequence, and involves a significant positive and/or negative ecological or economic interaction between the woody and non-woody components of the system.

Agroforestry also offers an opportunity for growing, under "plantation" conditions, multipurpose species whose productivity can be or has been improved by selection and/or breeding. Thus, wild, semi-domesticated and domesticated species can be used in the woody portion of the agroforestry system.

There is no clear distinction between forestry, agriculture and horticulture, especially where non-wood forest products are concerned (Wickens, 1990). Thus, depending on their scale and historical and national inclinations, plantation crops and their management can come under one or more of the three disciplines. The distinction has been further complicated by the development of agroforestry practices during the latter half of this century, where tree growing becomes part of the crop rotation, or alley cropping where the crops benefit from the adjoining permanent or semi-permanent rows of shrubs and/or trees. Multipurpose trees and shrubs are often selected for these practices, providing non-wood forest products in addition to their agronomic benefits by way of reducing erosion, providing shade and improving soil fertility.

In shifting cultivation, the bush fallow represents a natural and inefficient form of agroforestry. It is inefficient because the species regrowth and their density is usually subject to natural regeneration. For example, the gum cultivation cycle formerly practised in the Sudan traditionally consisted of about four years of cropping followed by ten to 14 years under tree fallow from regenerating *Acacia senegal*, with other trees and shrubs being largely eliminated during the previous clearings of the fallow for cultivation. This represents a management decision by the farmer to maximize production (within the limits of natural regeneration) of such non-wood forest products as gum arabic, browse and fuelwood.

Urbanization and demographic growth have made shifting cultivation largely impractical. Land under continuous cropping requires the rotation of crops to maintain fertility. Instead of a bush fallow, the planting of tree seeds or seedlings during the last year of cropping ensures a period of soil rejuvenation under a plantation crop, the regular spacing of which should maximize benefits from soil improvement and yields of non-wood forest products.

Management implementation

An example of the management ramifications required for the sustained productivity and conservation of non-wood forest products is that of the Niger's 77 000 km^2 Aïr and Ténére National Nature Reserve. The reserve was motivated primarily to conserve the region's unique flora and fauna against uncontrolled hunting and tourist harassment. After several years of drought, the effects of excessive land use and deforestation were clearly visible. The local inhabitants were consulted at all stages of planning to ensure their well-being and agreed cooperation.

The rural development programme included introducing adobe construction to decrease the demand for building poles, well digging, health training, adult literacy classes, etc. General state legislation was replaced by more appropriate site-specific regulations. A wildlife sanctuary occupying 12 percent of the area was established in the centre of the reserve, in a part rarely visited. Hunting and bushmeat gathering were banned and national restrictions on the use of certain tree species were enforced and accompanied by help compensating the artisans and products affected by the ban.

Concluding remarks

"Forestry is the science, business and art of managing and conserving forests and associated lands for continuing economic, social and environmental benefit. It involves the balanced management of forest resources for optimum yields of wood products, abundant wildlife, plentiful supplies of pure water, attractive scenic and recreational environments in wild, rural and urban settings, and a variety of other services and products. Forestry draws on knowledge and experience from many disciplines and other professions" (Science Council of Canada, 1973).

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Management for soil and water conservation

T. Michaelsen

This paper provides examples of different scenarios where soil and water conservation are seen as important aspects of sustainable forest management. It makes a brief update of present, incomplete knowledge of forest hydrology, especially in tropical zones and describes some forest management options, with special emphasis on soil and water conservation, including basic considerations in critical operations such as road construction, and land clearing. Finally, the paper deals with some of the particular issues related to semi-arid zones. The hydrologic balance of natural forests, once destroyed, can never be fully restored, and prevention through timely and decisive action is needed to protect forest areas which are vital for water resources protection from destruction and conversion to other uses, including forest plantations. On the other hand, it has been demonstrated that following a few basic rules in forest harvesting operations can make this practice environmentally acceptable in terms of soil, water and nutrient losses. The beneficial effects of trees and forest plantations on soil and water conservation should not be taken for granted. Forests and trees will only be protected and managed effectively if they are of value to the land users and to rural communities living in their vicinity.

SOIL AND WATER CONSERVATION MANAGEMENT

Forest management for soil and water conservation is carried out for many purposes or for combining several complementary or conflicting objectives. Scenarios range from cases where the only requirement is to establish norms for minimizing damage to soil and water resources by observing a few basic management rules – including road con-

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struction, land preparation, pest control and forest harvesting – to cases, such as municipal watersheds in humid tropical mountain areas, where the need for undisturbed forest cover may be so overriding as to exclude all activities that would affect or change the forest vegetative cover.

Sustainability in soil and water conservation aspects is not different from sustainability in other areas of forestry and land use in general. It is based on maintaining site productivity for sustained yield. In soil and water conservation projects, it was always assumed to be the main objective. In practice, however, it has been repeatedly demonstrated that this long-term objective was rarely achieved: the proposed technical solutions were too costly for large-scale implementation or even maintenance by land users, including the government and its relevant agencies. The challenge is therefore to make the concept of sustainability in forest soil and water conservation work. It is increasingly obvious that this depends on the perceived benefits of conservation activities to those directly affected, usually the rural populations living in or immediately near the areas.

Soil and water conservation in sustainable forest management

Single purpose water catchments. These are often small municipal water supply catchments in areas of high rainfall and steep terrain. Examples include the watersheds of the Guma Dam in Freetown, Sierra Leone; the Hermitage Dam in Kingston, Jamaica; and the Rio Piedras water intake, San Pedro Sula, Honduras. These three catchments, together with many others, are all relatively small (usually not more than a couple of thousand hectares) compared with their great importance as major suppliers of the domestic water requirement in urban areas. Furthermore, in most cases this importance was recognized by far-sighted town administrations early enough to save these catchments from shifting cultivation and uncontrolled urbanization. In general, they have been respected as water supply areas because the value of the water was, and is, much higher than the uncertain and short-term benefits from clearing, fuelwood cutting, grazing, etc. Although unpopular, the only forest "management" in such catchments should be effective patrolling by guards (forest or municipal) to protect the forest cover.

Water catchments, wildlife sanctuaries and large national parks. The combined status of a water supply catchment and a wildlife sanctuary or national park usually presents few technical problems.

The wildlife authorities in charge of such areas will normally maintain some protection which more than satisfies the watershed or water supply authorities. Examples can be found in Kenya (Mount Kenya and Aberdare National Parks) and the United Republic of Tanzania (Kilimanjaro National Park).

The same is true where natural forest areas in important watersheds are being protected because of the occurrence of rare plant species or for cultural or religious reasons.

Whereas successful water development has taken place downstream from national parks and other areas maintained under forest cover, it has rarely proved feasible to restore the forest cover fully upstream from new dams threatened by high sedimentation rates. Here, sustainability contains an element of timely and decisive action. Not only is prevention better than cure, but no cure may be available because, once people have settled in these watersheds, it is difficult to persuade them to move and because, once the forest is cut, it is difficult to restore the original hydrological balance

Forest recreation areas and watersheds. Mountain areas everywhere are being put under pressure by mass local and global tourism for hiking, skiing, camping, fishing, hunting and other activities. Further, "ecotourism", when changed from adventure travel for the few into nature observation tours for urban groups and to a source of revenue from the tourist industry, may become popular to the point of self-destruction. The image of mountain forests as peaceful areas for "getting away from it all" is being replaced by the reality of new alpine super highways, taking skiers directly to the mountains, which are complete with modified landscapes, hotels, skilifts and concrete avalanche control structures. Local culture, forests and scenic beauty in the Himalayas, the Andes and East Africa are rapidly changing because of international visitors. With such intensive activity, it is no longer certain that recreational use can be considered compatible with soil and water conservation functions of the forest cover. Careful monitoring and regulation are required, not only of forest management practices but also of the environmental impacts of recreational activities and related infrastructure.

Soil and water conservation in managed natural forests. Concerning human interventions, it is not always what is being done so much as how it is being done that matters. The positive or negative effects of natural forest harvesting on soil and water conservation will depend on the location of roads and trails, the quality of their construction, drainage and maintenance; the type of felling and hauling operations and degree of mechanization used; and the silvicultural interventions, including salvage felling and pest and fire protection, practised between harvesting cycles. As Hamilton (FAO, 1986) repeatedly noted, badly planned road construction in steep, humid tropical areas, followed by negligence and a lack of maintenance, may cause considerably more erosion and soil disturbance than shifting cultivation, often seen by government officials as the prime culprit of degradation.

However, it should be stressed that the combination of road construction – of any quality – and commercial timber logging makes natural forests extremely vulnerable, as they become accessible but of little commercial interest to anyone for the next 20 years. For the politician faced with demands of land-hungry peasants trying to feed their families, there appear to be only three alternatives: looking the other way and allowing spontaneous colonization; trying to regulate land-use conversions through agrarian reform programmes, transmigration, settlement schemes, etc.; or making sure that the forest is of value to the people living nearby, not only for employment during forest harvesting operations but also permanently as a source of food, water, fodder, housing materials, income, etc.

The maintenance of long-term site productivity in relation to forest harvesting operations is well summarized by Bruijnzeel (1990): "Significant rises in streamflow and dissolved nutrient concentration (notably of nitrate and potassium) have been observed after selective logging in Malaysia and Suriname. Losses can be minimised by taking proper care of road layout and extraction techniques, maintaining an adequate riparian buffer strip, etc. The increases in nutrient losses reported to date are temporary, relatively small and *should not create future productivity problems.* More work at a variety of geological substrates is desirable, also with respect to sediment production and sources" (italics added).

Forest plantations and soil and water conservation. The notion that tree planting is synonymous with soil and water conservation has become dominant in public opinion and the media. Furthermore, it is believed that the best way to make a "greener world" is to keep people away from such plantations. Both need further qualification: *i)* Tree plantations – of several species, including teak, pines, eucalyptus, and *Alnus nepalensis* – have been shown to suffer severe erosion problems shortly after canopy closure four to 15 years after planting and, in such cases, early interventions and thinnings, have been recommended to re-establish ground vegetation. Tree plantations *can* benefit watershed behaviour if properly planned and managed with this objective in mind. Forest plantations in watersheds will normally be multipurpose. If soil and water conservation is the only objective, then natural regeneration should be preferred if it is at all feasible. On some eroded sites, pioneer tree species and grasses may need to be planted to start the process of revegetation. *ii)* If people are denied access to plantations occupying former degraded rangelands, they will usually make sure that the plantation remains unsuccessful and/or they will have to take their animals to graze elsewhere, most likely on even more marginal land and, thereby, causing harmful downstream effects.

Mixed land-use and soil and water conservation. Most watersheds in tropical and subtropical zones are not completely forested, but often densely inhabited by a rural population practising subsistence farming.

Again, such watershed land uses are neither inherently "good" nor "bad": well-managed terraced fields may be as stable as forest plantations, and cut-and-carry grass plots or rotational grazing may have erosion and runoff rates that are almost as low as forested land. However, forests in mountain areas have only rarely been replaced with other well-managed and sustainable forms of land use. At present, therefore, many mountain areas badly need restoring.

Trees and forests in the hydrological cycle and soil and water conservation

The intention here is not to give a full description of the hydrological cycle and the role played by forests and woody vegetation. However, the last decade has witnessed noteworthy progress in the understanding of tropical and subtropical forest hydrology which may help in understanding what trees and forests can and cannot do to make proposed land uses sustainable.

Interception and infiltration. Moisture interception by vegetation, woody or not, generally means two things: *i)* that, with a rainfall pattern of low intensity showers, most moisture does not reach the ground but is directly returned to the atmosphere by evaporation from leaves, stems, branches, etc.; and *ii)* that, even during very intensive storms, raindrops will not hit the soil directly, thus avoiding the first step in soil erosion – detachment of soil particles. However, depending on local conditions, three more aspects of interception may be important: interception of mist and "horizontal" rainfall; interception by tree canopies with limited ground vegetation or litter; and heavy rainfall.

The interception of horizontal rain is important in cold deserts such as that of northern Chile, or in cloud forests in Central America from about 2 000 m above sea level. Otherwise, there are many other examples with special local conditions where this interception significantly contributes to soil moisture.

The interception by tree crowns several metres above the ground does not help soil protection and may, in some cases, even increase erosion by magnifying the size of raindrops falling from the leaves compared with those of the rain. This frequently happens with large-leaved species such as teak, but is not limited to this species. This may cause soil erosion on sloping land where forest plantations are allowed to establish a closed canopy and where trees shade out ground vegetation, including crops under agroforestry systems.

During tropical storms with precipitation exceeding 100 mm in two hours, interception capacity loses significance for reducing surface runoff but the forest cover may still act as a mechanical protection against the direct impact of raindrops on the soil surface.

Infiltration rates under natural undisturbed forest cover will usually be high and surface runoff a relatively rare phenomenon limited to unusually big rainstorms. The influence of the forest cover is related principally to the fact that the ground will be covered with litter and that the organic matter content of the soil is maintained. In addition, roots, whether live or decaying, will provide pore space over and above those dictated by soil texture.

However, once this additional space has been saturated, further infiltration will be determined by soil texture irrespective of vegetative cover or land use, with the possible exception of overgrazed pasture where the soil infiltration rates may be reduced by trampling.

Water use by trees. Water used by trees and forest vegetation is a continuing and sometimes hotly debated issue with important practical implications. In temperate zones, trees have been planted to drain swamps and lower water tables. The famous controlled paired watershed studies carried out at the Coweeta Hydrologic Laboratory in North Carolina, United States, since 1934 showed very clearly that there was scope for increased water yield by reducing forest vegetation (Swank and Crossley, 1988).

However, subsequent research in tropical and subtropical regions has shown that these results cannot be translated directly to the tropics, especially because of the erosion risks involved from high rainfall frequencies and intensities. In the tropics, vegetation reduction to increase water yields cannot be recommended. On the contrary, observations in the Phewa Tal watershed in Nepal showed that in some cases increased infiltration following reforestation of degraded communal grazing areas more than offset the water used by the trees and that springs started to flow longer into the dry season.

Tree species that use more water than others constitute one of the motives behind the FAO study, *The ecological effects of eucalyptus* (FAO, 1985). However, it was found that this species was as efficient as others in producing biomass based on available water. Thus eucalyptus plantations will normally use more water than natural vegetation because of the amount of biomass produced; eucalyptus planting is therefore not recommended in catchments where water concerns prevail over wood yields. The same recommendation concerns other fast-growing species, including pines, hence such watersheds should remain under natural vegetation as far as possible. Again it must be stressed that in tropical mountain areas there is not much scope for increasing water yield by reducing vegetative cover.

Forests and rainfall. There is no evidence that even large-scale deforestation has led to reduced mean annual precipitation rates or that reforestation schemes would be able to increase rainfall. Apart from special localized cases, rainfall is determined by atmospheric conditions and low pressure systems, not by land conditions (Pereira, 1989).

Therefore, it can be generally stated that deforestation does not lead to droughts, as sometimes stated in the media. Land degradation following the elimination of forest vegetation through unsuitable cultivation practices, overcutting and overgrazing may give the impression of lower rainfall. However, this is not reflected in long-term weather records.

Forests and floods. The fact that undisturbed forest cover maintains high infiltration rates and soil water-storage capacity does not mean that natural forest areas will effectively reduce runoff beyond certain limits. When more than 100 mm of rain falls in a couple of hours on the north coast of Jamaica, or when around 400 mm falls during a 24-hour period in southern Thailand or Honduras, then even high infiltration rates and soil storage capacities will be exceeded and any additional rainfall will be surface runoff, contributing to downstream floods (Hamilton in FAO, 1988).

As Hamilton pointed out (FAO, 1986), foresters should not yield to the temptation of using flood control to justify the funding of reafforestation schemes, since they will not be able to deliver because: *i)* the original conditions under natural forest cover can only be partially restored; and *ii)* flood damage is "caused" by exceptional amounts of rainfall greatly exceeding the retention capacity of any land, forested or not, and by floodplain occupation downstream.

Management options for sustainable soil and water conservation

Soil and water considerations constitute the sole objective of forest managements only in a few cases, such as small steep municipal watersheds. Therefore forest management options with multiple objectives are discussed here.

Natural vegetation and plantations. Plantations have often been used by government forest services, even when the main objective was land reclamation, which could have been achieved more suitably, both economically and biologically, by regenerating natural vegetation. The argument was that the local population would not respect the protection of natural regeneration in the same way as with a plantation, commonly of exotic pines. However, with the increased understanding that sustainability can only be achieved with the active participation, from the planning stage, of the local population, a change is due in the way forest service activities are implemented.

Gradually, costly monospecific plantations of exotic trees for soil protection should be considered unnecessary. The objective should be to rehabilitate and maintain natural vegetation sustainably, based on managed grazing and agreed multiple-use forest management plans, implemented with the active involvement of the local population.

Plantation management for soil and water conservation. Where land suitability and the long-term land-use objectives indicate forest plantations as the best option for watershed management, it is still possible to consider a range of alternatives aimed at optimizing the soil and water conservation benefits of such plantations.

As already mentioned, forest plantations do not necessarily provide good soil protection unless litter and ground cover is favoured and maintained, mostly through early thinnings, pruning, etc. Similarly, grasses and other low vegetation can be stimulated by varying planting distances, including greater distances between rows, on the contour if possible, than within rows: 2 x 4 m rather than 3 x 3, for instance.

Often some forest grazing is desirable in order to reduce fire hazards. Such grazing should be controlled and managed and preferably consist of high stocking rates for short periods followed by long periods of rest. When carried out in close collaboration with livestock owners, this silvicultural practice may also develop into constructive cooperation between foresters and farmers or ranchers and make both groups equally interested in forest protection.

Although management is emphasized, species selection remains an important factor. In most cases, however, the decision to plant rather than rely on natural vegetation would have been based on the mix of major and minor forest products required. Species selection would be based on this factor, combined with an analysis of the corresponding site factors, including soil and water conservation. Species selection should always be based on local criteria and objectives. It therefore seems inappropriate to make general recommendations about one species or another, mixed or pure plantations and so forth.

Where planting is necessary for watershed rehabilitation, increased attention is being given not only to providing vegetative cover but, at the same time, to addressing some of the original causes of land degradation: overexploitation for fuelwood, overgrazing, browsing, poor farming practices, etc. In such cases, it is first necessary to ensure a participatory planning process involving the land users and to obtain consensus on what to plant and for what purposes – fodder, fuelwood, building material – in order to achieve sustainable protection rather than short-term official targets of "regreening".

How sustainable are agroforestry production systems? The sustainability of agroforestry production systems is based on three major factors: maintenance of biomass production levels; return per person-day to the farmer compared with alternative sources of income; and maintenance of site productivity and other environmental factors. A common assumption, largely proved to be false, is that the presence of many trees by itself would ensure soil stability and water conservation (Wiersum, 1984; Young, 1988). On the contrary, rather than looking up into the tree crowns, it is necessary to look down at the ground cover, in order to assess the effectiveness of trees in soil conservation.

Soil and water considerations in land clearing and forest harvesting

Land clearing. The impact on soil and water conservation from land clearing depends almost entirely on the methods and technology used: the most environment-friendly methods are those used by small-scale shifting cultivators, involving only manual felling and burning followed by planting without tillage; the other extreme is represented by felling or "chaining" followed by destumping with bulldozers.

An intermediate impact results when the land is cleared mechanically but following the contours and with the debris placed as barriers to slow down runoff and erosion. This can by further improved by respecting natural watercourses, leaving buffer strips untouched and avoiding steep parts of the terrain which are usually unsuitable for the intended use anyway. Sadly, however, such simple and effective measures are often ignored in land-clearing operations if they add – even minimally – to short-term costs.

Road and trail construction and maintenance. One of the favourite and well-founded targets of public criticism of tropical forest operations is the conspicuous damage caused by inappropriate road construction and the lack of maintenance of forest roads.

The divorce of responsibility between who pays for the initial construction and who, if anyone, pays for long-term maintenance leads to too many kilometres of cheap roads being "built" with inadequate drainage systems, no protection of cut-and-fill slopes and gradients that are too steep. It is not exaggerated to state that no forestry operation can even pretend to be sustainable if the road and trail network is not designed, built and maintained in an environmentally satisfactory manner.

Forest harvesting. The same principles applying to land clearing also cover forest harvesting operations, with one important exception: high mechanization may be very appropriate if it means avoiding ground skidding. Nevertheless, attention should be given to road and trail construction, landings, etc.

Modern forest harvesting *can* be carried out in ways that minimize environmental damage and hence provide the basis for sustainable forest management. However, this almost always involves higher operational costs and, judging from experiences with land clearing and road construction, requires a closer relationship between the short- and long-term beneficiaries of forestry operations, including downstream populations and economic and environmental interests.

Conversion to other land uses. Much of the current annual deforestation in tropical and subtropical zones is due, not to logging and other forest harvesting operations but to a process of converting forested areas to other land uses. This involves at least two critical considerations: land-clearing methods and the sustainability of the "new" land use.

As stated above, environmental damage caused by different land-clearing methods varies considerably. If the proposed land use is not sustainable, further land clearing will soon be necessary to compensate for dwindling income and food production. Hence this is one of the main reasons why planners increasingly link deforestation with poverty and unsustainable agriculture.

On the other hand, even foresters and forestry agencies should welcome careful clearing of forested land for more valuable and sustainable land uses except, naturally, where ecologically significant or unique areas are involved. The delineation and protection of such areas, and not a general defence of any land covered by forest vegetation, should be the challenge of the forestry profession.

Soil and water conservation in semi-arid zones

Emphasis on natural vegetation. Large-scale conversions of natural vegetation in tropical and subtropical semi-arid zones to monospecific plantations of cash crops in agriculture (cotton and others) and forestry (pines, eucalyptus and others) have often proved to be financially unsustainable – because of market fluctuations, increased labour costs, quotas, product substitutions for example – or environmentally harmful – because of increased wind or water erosion, excessive needs of pesticide application, etc. This has led to renewed interest in multipurpose management of existing, but often degraded, natural vegetation.

This is by no means a simple alternative. It implies reviving the respect for traditional grazing rights and regulating mechanisms; developing and marketing semi-arid forest and range products (oils, fruits, nuts, meat, skins, honey, wood, fodder, silk, wool, etc.); and reorienting government and non-governmental institutions and services available to the rural communities.

The large-scale forest hydrological restoration of semi-arid lands carried out by the government in the Spanish Mediterranean zones is not an option generally available to tropical and subtropical countries, as it is based on a gradual depopulation of the mountain areas and on the availability of sufficient public funds. However, large-scale forestation *can* provide a valuable injection of external financing to initiate programmes to rehabilitate and diversify the mountain economy, as is happening in Turkey and Pakistan, for example. On the other hand, if such projects remain largely government-executed public works, they may be short-lived or even rejected by the rural populations; this happened with soil conservation programmes in Lesotho (FAO, 1990) and with mountain restoration works in the early 1970s in Iran.

Land preparation for planting. When the planting of forest species is required in semi-arid zones, certain mechanical measures are usually necessary to ensure water retention and infiltration: these may be eyebrow terraces, single or double furrows along the contour, pits, ditches or even terraces, as practised in Ethiopia and China.

However, considering land reclamation as part of mountain rural development and not just as a reforestation project means that any opportunity for water retention, storage and infiltration should be utilized, since this will translate into livestock and agricultural development in nearby downstream areas, as currently demonstrated by the UNDP/FAO-assisted Suketar watershed project in Azad Kashmir, Pakistan.

The fact that such reclamation projects are feasible once again demonstrates that semi-arid zones have generally suffered from human-caused degradation, not desertification. Rainfall has remained remarkably consistent, with the natural fluctuations typical of semi-arid zones, even over thousands of years as the history of Yemen and other countries show.

The role of fodder and livestock. The role of fodder and livestock in forestry development in semi-arid zones cannot be ignored and should not be underestimated. Three aspects of land management can help improve the dialogue between foresters and livestock owners: more attention to the potential of fodder trees; water harvesting and water conservation measures for increased fodder production; and the use of controlled grazing to reduce the fire hazard.

Large-scale reforestation in semi-arid zones may affect watersheds negatively if it fails to consider the above. Apart from alienating livestock owners, who are often influential members of society, the displacement of livestock from traditional grazing areas may lead to more marginal areas being grazed, as herds are almost never reduced as part of a forestry programme. In the medium term, such reductions are unnecessary, since rehabilitated rangeland often produces more fodder after reforestation than before.

Windbreaks and shelterbelts. Tree planting for windbreaks not only conserves moisture and reduces the effects of wind erosion, but may be an essential basis for agriculture in semi-arid zones and windy temperate areas such as northwestern Europe. This has been clearly demonstrated in Denmark during the last 25 years: first the introduction of large farm machines caused important windbreaks to be eliminated in order to create large, consolidated fields suitable for such mechanization; second during the period following the oil crisis 1973, when trees in windbreaks were cut for fuelwood. In both cases, wind erosion was reactivated, reminding people of the essential functions of the shelterbelts, which in most cases had to be restored.

Elements of a strategy for the future

Sustainable forest management for soil and water conservation cannot be separated from the social and economic conditions generally governing society. It cannot be a "green island" in a sea of land degradation and poverty. If government agencies are ineffective outside the forest, they may be even more so inside. The first guiding principle should therefore be to consider forests in the national and local socio-economic context.

Second, it is useful to distinguish between six different scenarios: *i)* natural forest which should be protected in its natural state for water, wildlife and genetic resources conservation; *ii)* natural forest subject to the harvesting of timber and non-wood forest products according to a forest management plan; *iii)* forest plantations; *iv)* land-use conversions to plantation crops, pastures, agroforestry, agriculture, urban land uses; *v)* natural forests in semi-arid zones; and *vi)* shelterbelts and other environmental tree planting. Each of these will need specific action, with many cases of overlapping, mixed land-use patterns, buffer zones, etc.

Third, people and communities affected should participate in planning and distributing benefits. If the land users and the local communities in general have no incentive to protect forest resources, no police force in the world will be able to prevent these resources from disappearing.

Finally, institutions, including government agencies and farmers' and peasants' organizations, must be given continuing support to ensure long-term stability. Otherwise, no confidence will be attached to agreements, management plans, grazing rights, etc.

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Ensuring sustainable management of wildlife resources: the case of Africa

S.S. Ajayi

This paper describes the depleted state of African wildlife and outlines some positive measures for its sustainable management. Some examples demonstrate this depletion: the number of African elephants has decreased from about ten million (500 years ago) to just 700 000 today; the number of rhinoceros dwindled from 50 000 in 1976 to 14 800 in 1978, and only about 3 500 existed in Africa by 1989. Poaching and hunting are among the main causes of this depletion. The economic values of wildlife are divided into two main headings: consumptive uses – for meat, trophy value and game ranching; and non-consumptive uses – tourism and recreation. Measures for managing African wildlife sustainably can be negative or positive. Negative measures include management by alienating local communities from wildlife by repressive game-use legislation, forcibly moving people from their ancestral homes, severing cultural ties and totally banning utilization and commercialization. This only increases the price of animals as well as the risk of poaching. Positive measures include integrated wildlife utilization with local community participation; multiple uses for sustainable management of wildlife – game viewing, hunting, tourism, mixed wildlife/livestock farms; wildlife as a form of land use on marginal lands; and domestication.

AFRICA'S WILDLIFE ENDOWMENT AND ITS DEPLETED STATUS

Africa has more wildlife resources than any other continent in the world (Bigalke, 1964). According to Mwenya (FAO, 1990a), it is an intrinsic part of African economic and cultural life. The World Bank in 1989 estimated the original wildlife habitats of Africa to be 20 797 441

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square miles (almost 54 million km^2). However, today African wildlife is a depleted resource. According to the World Bank (1990), many species which were previously abundant are now extinct or gravely endangered. The World Bank currently estimates that, of the original wildlife habitats, 65 percent has been lost through conversion to agriculture and livestock grazing as well as overcutting for fuelwood. The remainder is under growing pressure to meet the needs of stressed national economies and rapidly growing human populations. Habitat loss is thus one of the greatest threats to wildlife in Africa.

According to the World Conservation Union (IUCN, 1989), hunting has decimated many species of African wildlife. The ivory trade has reduced the number of African elephants from about ten million (500 years ago) to 700 000 today and the destruction continues at the rate of 10 percent annually.

Furthermore, according to Simmons and Kreuter (1989) rhinoceros dwindled from 50 000 in 1976 to 14 800 in 1978 and 8 800 in 1984 while only about 3 500 existed on the entire continent of Africa by 1989.

Milligan and Ague (1978) found that the biomass of large herbivores in 11 national parks in West Africa ranges considerably from 214 kg per km^2 in Comoe (Côte d'Ivoire) to 4 032 kg per km^2 in Saint Flogis (Central African Republic). These figures are quite below the potential carrying capacity of the habitats. They attributed the low population densities to *i)* the degradation of wildlife habitats; and *ii)* high mortality rates from overhunting, since many traditional hunting grounds have been transformed officially to forest or game reserves, where all hunting rights are illegal.

The declining status of wildlife in Africa can also be seen from the wildlife legislation of most African countries. According to the Organization of African Unity (OAU) Algiers Wildlife Convention of 1968, animals were usually classified into three schedules. Provision was to be made in national legislation for: animals that are endangered and should be strictly protected (as Schedule I); animals that are not endangered and vulnerable but can be hunted under exceptional circumstances (as Schedule II); and those animals with satisfactory status and which, therefore, can be hunted under licence (as Schedule III). However, Ajayi (FAO, 1979) in his survey of forest mammal utilization in West Africa, found that the wildlife legislation used was old and outdated and that the current status of wildlife showed a staggering list of endangered mammals which were not strictly protected by law. According to this report, ten species of the order Primate, one of Proboscidae, five of Artiodactyle, 23 of Carnivora, two of Rodentia and three of Philidota represent a realistic current list of endangered species of mammals in West Africa.

Ayeni (1977) found that the decline of wildlife populations in Nigeria can be attributed to poaching. Interviews with numerous poachers arrested inside protected areas revealed that poachers hunted primarily for meat and money, as poaching was considered more lucrative than farming. They engaged in illegal hunting because of starvation and persistent poverty among the local communities. Weak wildlife laws, which prescribe a token fine for convicted poachers, were also responsible for persistent illegal hunting.

The declining status of African wildlife resources requires an urgent, realistic and effective approach, necessarily incorporating the root cause of persistent poaching among the local communities.

ECONOMIC VALUE OF WILDLIFE

Consumptive uses

For meat. *Dependence of rural population on wildlife.* Wildlife is a very important source of meat, particularly in the forest regions of West Africa where tsetse flies have limited domestic livestock rearing. Table 1 shows the economic importance of forest mammals in five West African states and relates the percentage mean annual consumption of animal protein to human populations. In all the countries, meat from wildlife (popularly known as bushmeat) accounts for 20 to 90 percent of total animal protein consumed. In Liberia, wildlife accounts for as much as 80 to 90 percent of the total animal protein consumed.

In Ghana, an estimated 1.75 of the 15.22 g of daily protein consumed came from wildlife, compared with 1.64 g from domestic livestock. The rest comes from plants and fish (Asibey, 1978).

In Nigeria, Charter (1970) estimated that a total of 617 tonnes of bushmeat were consumed during the financial year 1965/66 compared with 714 tonnes of beef during the same period. The estimated value of wild animal meat for this period was $20.4 million against $34 million for domestic animals.

For locally produced food, Charter stated that 19 percent came from wild animals, 21 percent from domestic animals and 60 percent from fish. He concluded that Nigerians, particularly in the southern forest region, depend more on their natural environment for animal protein than on agriculture.

In southern Africa, Von Richter (1970) found that nearly 60 percent of all animal

TABLE 1
Economic importance of forest wildlife in five West African countries

Countries	Mean annual consumption of wild animal protein	Source	Human population (*Millions*)
Cameroon	70-80% among rural people in the southern rain forest	Allo (personal communication, 1979)	7 5 (1978)
Côte d'Ivoire	70% for the southern tropical rain forest before hunting was banned in 1974	Asibey (1978)	6 0 (1978)
Ghana	73% for the entire country	Asibey (1978)	10 3 (1974)
Liberia	80-90% for the entire country	Woods (personal communication, 1979)	2 0 (1978)
Nigeria	20% among rural people in the southern rain forest	Charter (1970)	8 0 (1973)

protein consumed by people in rural areas in Botswana came from wildlife. Bigalke (1964) also discovered that wildlife represented 5 to 10 percent of the total meat consumed in some localities in Rhodesia (now Zambia and Zimbabwe).

Carcass value. Although wildlife is widely utilized for food in Africa, less is known about carcass and nutritive values than for domestic animals. Apart from Asibey and Eyeson (1975), Tewe and Ajayi (1977), Ajayi and Tewe (1979), Ajayi and Tewe (1979), there is little published information on the nutritive quality of forest mammals and domestic animals in West Africa.

Table 2 compares the percentage dressed carcass value of pig, sheep, cattle, domestic rabbit and some wild rodents such as the grass cutter and the African giant rat. Wild rodents compared favourably in carcass quality with rabbits and other domestic animals.

Nutritive value. Table 3 compares the nutritive values (fat, protein and ash [carbohydrates]) of some West African forest mammals and domestic animals. Domestic animals generally have less protein and carbohydrates than their wild counterparts: carbohydrates range from 1.1 percent in red river hog to 6 percent in forest genet, whereas for domestic animals in similar environments they range from 0.8 percent in pork and beef

TABLE 2
Killing-out percentage of some forest and domestic mammals in West Africa

Animal species	Average killing-out (Dressed carcass value)
	(Percentage)
Domestic rabbit	51 4
Cattle	38 8
Pig	74 8
Sheep	49 3
Dwarf forest goat	50 6
Grass cutter	63 8
African giant rat	51 6

to 1.3 percent in mutton. Likewise, proteins range from 16.1 percent in tree hyrax to 55.4 percent in forest genet. For domestic animals, there are lower values: 11.2 percent in pork to 19.6 percent in beef. However, further research into more varied wildlife species and their approximate composition and amino acid content is necessary to establish the alleged higher nutritive value of wildlife over domestic livestock.

Trophy value. The vulnerability of elephant and rhinoceros can indeed be attributed to their enormous economic value. Uncarved tusks in East Africa sold for $5 per kilogram in 1969, $68 in 1978 and $180 in 1989 (Simmons and Kreuter, 1989). Elephant hide is worth as much as the ivory and is made into boots, wallets and other leather goods. Thus, the value of one elephant (excluding its meat) is about $4 000. Rhinoceros horns are valued as dagger handles and aphrodisiacs; the horns were sold for about $16 000 per kilogram in 1989, and since each horn weighed about 5 kg, one rhinoceros (excluding its meat) was worth about $80 000.

Game ranching. Game ranching and mixed wildlife farming have been well-established and profitable practices in southern Africa for over 30 years. In Transvaal, by 1964 there were 4 000 ranches involved in game farming, with an annual output of over 3 500 kg of game meat per year. Wildlife now earns about $35 million per year.

Recently, trophy hunting in southern Africa has increased substantially. Farms are generally small – about 3 000 ha – but safari trophy hunting in this part of Africa accounts for about 47 percent of the African market.

In Namibia too, the game ranching industry has developed rapidly within the past 35 years. Since 1967, when Namibian legislation allowed landholders full ownership of wildlife as well as leased hunting rights, ranches using wildlife as a primary form of land use increased from 52 in

TABLE 3
Approximate composition and mineral content of forest mammals and domestic animals

Animal	Moisture	Protein (grams)	Fat	Ash
FOREST MAMMALS				
Rodents				
African giant rat				
(*Cricetomys gambianus*)	65 9	18 9	11 0	3 9
Grass cutter				
(*Trhyonomys swinderianus*)	65 8	20 7	0 7	0 5
	#77 4	#26 2	#7 4	#1 0
	69 7	18 8	8 9	1 2
Tree hyrax				
(Dendrohyrax arborens)	78 7	16 1	2 9	1 9
Primates				
Green monkey				
(*Cercopithecus aethiops*)	80 3	17 6	1 3	1 1
Proboscidae				
Elephant (skin)				
(*Loxodonta africana cyclotis*)	49 4	29 2	19 7	1 7
Carnivora				
Long-snouted mongoose				
(*Herpestes naso*)	72 7	18 8	1 9	3 3
Forest genet				
(*Genetta pardina*)	31 8	55 4	9 3	6 0
Suidae				
Red river hog				
(*Potamochoerus aethiops*)	70 1	23.8	1 6	1 1
	#72 4	#27 2	#2 7	#1 1
Artiodactyla				
Royal antelope				
(*Nectragus pygmacus*)	45 1	40.6	10 7	3 3

TABLE 3 *(continued)*

Animal	Moisture	Protein	Fat	Ash
		(grams)		
Grimm's or Grey duiker				
(*Sylvicapra grimmia*)	74 5	23 4	0 9	1 2
	74 6	20 8	3.4	1 2
Bushbuck				
(*Tregelaphus scriptus*)	59 9	33 4	2 0	4 0
	47 6	40 9	12 2	3 7
DOMESTIC ANIMALS				
Ox (beef)	+73 8	+19 6	+12 0	+1 0
	+54 7	+16 5	+28 0	+0 8
Sheep (mutton)	+78 5	+17 2	+2 9	+1 0
	+62 4	+16 8	+19 4	+1 3
Pig (pork)	+64 8	+19 4	+13.4	+0 8
	+41 1	+11 2	+49 0	+0 6

Note Approximate values are expressed in terms of g/100 g and minerals in mg/100 g of fresh edible tissue
Sources +Tewe and Ajayi (1977), #Ajayi and Tewe (1979), and Asibey and Eyeson (1975) Other figures without symbols were derived from Ajayi (1979)

1976 to 411 in 1979. In this way, the populations of most wildlife species increased by 30 percent. In the early 1980s, four private farms initiated cropping schemes, exporting $2.1 million worth of meat to Europe. Sport hunting generated another $1.2 million and live animal exports a further $0.6 million.

Game ranching is thus growing rapidly, mainly because of the multiple uses of wildlife and because of the quasi-private ownership of the resource.

Non-consumptive uses – tourism

Wildlife-based tourism development has been the backbone of the economies of some East and southern African countries. For example, Ajayi (1972) found that wildlife-based tourism contributed about $30 million to Kenya's economy in 1971.

In countries of the Southern African Development Community (SADC), it is estimated that wildlife utilization for tourism could generate an annual income of about $250 million. This estimate is thought to fall far short of southern Africa's full potential (FAO, 1990b). Apart from the monetary value, wildlife-based tourism has many advantages as a form of land

TABLE 4
Profit assessments for ranch case-studies in Zimbabwe, with environmental costs

Ranch	Wildlife	Cattle
	(US$/ha)	
Buffalo range	4.90-6 21	-8
Rosslyn ranch	5 29	0
Matetsi region	4 18-8 93	-1 18
Matetsi safari area	5 14-11 54	0

Note Values converted at $Z1 = US$0 72
Source Child, 1988

TABLE 5
Profit assessments for ranch case studies in Zimbabwe – without environmental costs

Ranch	Wildlife	Cattle
	(US cents/kg)	
Buffalo ranch	13-18	-4
Iwaba ranch	17-25	7-10
Midland region	17	7
Lowveld region	32	7
Nuanetsi ranch (Lowveld)	2 6	1 7

Note Values converted at Z$1 = US$0 72.
Source Child, 1988

use over other forms of wildlife utilization and land-use systems: animals are not consumed so that each population of animals can be used several times over; the "commodity" being sold in the case of game-viewing tourism and safari hunting is not the animal itself but the "experience" of hunting it or seeing it in its natural setting.

Another feature of non-consumptive recreational use of wildlife is environmental sustainability. Increasing income from wildlife in this sector does not imply increasing the number of animals, but rather the number of tourists and possibly safari hunters as well as the fees charged.

Economic value of game ranching and cattle production

Child (1988) made several comparisons of cattle and wildlife production in Zimbabwe both considering environmental costs (Table 4) and without considering environmental costs (Table 5). These studies show that wildlife is far more profitable than cattle. When the effects of production on the environment are considered, wildlife is so profitable that several cattle ranches run at a loss.

The Matetsi provides a good example of the advantages in shifting from cattle to wildlife enterprises. In 1973, the area was expropriated from cattle ranchers and designated for safari hunting. Matetsi now supports a wide range of wildlife species and generates a net profit of $5 per hectare. Moreover, the land has been considerably upgraded under wildlife management.

TABLE 6
Economic values of different wildlife uses in East and southern Africa

Wildlife utilization	Characteristic	Profit (US$/ha)
Tourism (non-consumptive)	High-intensity, Tanzania (Manyara)	250
	High-intensity, Kenya (Amboseli)	1 500
	Medium-intensity, Tanzania (Serengeti)	8-18
	Low-intensity, Tanzania (Ruaha)	0 10
Safari hunting (lightly consumptive)	Sport hunting, Tanzania	0 9
	Sport hunting, Zimbabwe (Matetsi)	5-10
	Sport hunting, Zimbabwe (ranches)	3-6
Local community integrated wildlife utilization on marginal lands (consumptive and non-consumptive)	Agriculture, Zimbabwe	0
	Game culling, safari hunting and tourism in Zimbabwe	
	• Total income	2
	• Income to local communities	1

Comparative economic values of consumptive and non-consumptive uses of wildlife

In 1989, the World Bank compared different forms of consumptive and non-consumptive wildlife utilization in the United Republic of Tanzania, Kenya and Zimbabwe and found that tourism is by far the most lucrative of all enterprises (Table 6). It earns an annual profit of about $1 500 per hectare in high-density areas such as the Amboseli National Park in Kenya and $250 per hectare in the Manyara National Park in Tanzania. This is followed by sport hunting in Zimbabwe. Local community integrated utilization of wildlife generates a total profit of about $2 per hectare, of which about 50 percent accrues to local communities in Zimbabwe.

NEGATIVE MITIGATION MEASURES FOR SUSTAINABLE MANAGEMENT OF AFRICAN WILDLIFE

Alienation of local communities: a problematic solution

In the nineteenth and the first part of the twentieth century, most of Africa was colonized by Europeans. Large areas containing wildlife and other natural resources were set aside for "conservation" under state ownership. Thus, relatively high-density wildlife areas in many parts of Africa were owned by the colonial government. Rural communities, the traditional owners of wildlife resources, were forcibly moved out of their ancestral areas of land and consequently alienated from the wildlife that they once owned (FAO, 1990b; 1990c; 1990d).

This alienation of Africans from their wildlife was backed by repressive legislation with no respect for chiefs, rural communities and their traditional and cultural values.

This conservation approach had grievous consequences: it cut into the heart of long-held traditions and customs that were an integral part of African existence and, according to Mwenya (FAO, 1990a), it dismembered the entire holistic philosophy underlying the structure of African life. Deprivation thus evoked a strong sense of injustice among the African rural communities who lived closest to wildlife, to the extent that they resorted to poaching. The colonial and postcolonial governments responded by adopting a vigorous militaristic anti-poaching campaign.

Thus, the problems arising from this management approach can be summarized as follows:

- Local communities were virtually excluded from access to natural resources, particularly wildlife and forest reserves, despite the fact that the community pays the major price for natural resources conservation in terms of alienated land, lost opportunities for resource use and damage to crops and livelihood by wildlife.
- Traditionally and culturally, African communities were originally linked with their natural resources. However, conservation policies have tended to sever these linkages. Rural communities participated very little or not at all in conservation decision-making and in utilizing the benefits.
- Communities near designated conservation areas continue to suffer from underdevelopment, since money from natural resource utilization does not "filter down" to the grassroots. Consequently, these remote areas have poor social amenities and severe unemployment problems.
- The community's interaction with wildlife and other natural resources is often termed illegal under the existing repressive legislation. Therefore, the natural resources have continued to suffer severely from poaching.

Total ban on utilization and commercialization

One approach to elephant and rhinoceros conservation in Africa today is a total ban on exploiting these two species in order to suppress or eliminate trade in ivory and rhinoceros horns. The trade has resulted in the loss of 56 to 78 percent of elephant populations in East and central Africa, mainly to poachers. This conservation approach was said to be characteristic of an economic theory that a government ban on a valuable commodity can never wholly eliminate the demand (Simmons and Kreuter, 1989). Hence, the total ban achieved three results: a price increase of the commodities – ivory and rhinoceros horn; people who had comparative advantage for avoiding detection, particularly government officials, took over the formerly legal market; and the resources disappeared.

It must be remembered that so little was spent on patrolling the protected areas that the chances of catching poachers was minimal. Game guards are ill-equipped, underpaid and sparsely scattered in reserve areas. Despite the total ban on wildlife exploitation, the more lucrative business of poaching is such a powerful incentive that the very government officials charged with the primary responsibility of protection sometimes became the worst criminals. This management approach failed because *i)* it misplaced the responsibility for wildlife protection and management utilization, putting it in "government hands" instead of those of the local communities living near the protected areas; and *ii)* it was unable to address the basic problems of starvation, poverty and unemployment, which Ayeni (1977) identified as the root cause of illegal hunting.

POSITIVE MITIGATION MEASURES FOR SUSTAINABLE MANAGEMENT OF AFRICAN WILDLIFE

Integrated wildlife utilization with local community participation

Practically all the former colonial African countries underwent the above experiences in their bid to conserve what was left of their wildlife resources. However, southern African countries are increasingly aware today that wildlife and other natural resources cannot be managed successfully without the involvement and participation of local communities in the decision-making processes and in the distribution of the resulting economic benefits.

Against this background, the communal integrated resource conservation programmes were established in three southern African countries – Botswana, Zambia and Zimbabwe – literally to return the natural resources to the "owners" so that communities might keep, manage and utilize their resources (FAO, 1990b; 1990c; 1990d). This is the origin of the Game Harvesting Project in Botswana; the Luangwa Integrated Rural Development Project (LIRDP); the Administrative Management by Design (ADMADE) project in Zambia; and the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) in Zimbabwe. This current philosophy of local community participation in wildlife management is therefore considered the basis of modern wildlife management projects in Africa. It has resolved many sociopolitical problems and has reduced poaching to the bare minimum in many parts of Africa.

These integrated wildlife utilization schemes aim at generating income and employment for the local communities. As the local communities are responsible for managing their wildlife resources, wildlife conservation in these projects has also improved in terms of greatly reduced poaching and increased wildlife populations and habitat upgrading.

Quasi-private ownership and commercialization of wildlife. In June 1989, a report by the Ivory Trade Review Group (ITRG) concluded that the ivory trade, and not habitat loss or human population increase, is responsible for the declining numbers of African elephants. Some East African countries – notably Tanzania and Kenya – responded with an immediate total ban on the ivory trade. The European Economic Community correspondingly banned ivory imports.

The East African countries also requested the secretariat of the Convention on International Trade in Endangered Species of wild flora and fauna (CITES) to list the elephant in Appendix I: this would amount to a total ban on trade in elephant products, including hides and ivory; the African elephant is currently listed in Appendix II, which allows a quota allocation to be administered by CITES for their utilization.

The old approach of total bans has now shifted to conservation by utilization. This new approach, practised by Zimbabwe, Malawi, Botswana, Zambia and South Africa, allows ecologically-based culling of elephants at the rate of 5 percent per year on private, communal and state lands. Photographic and safari opportunities are also sold to international clients. This strategy has resulted in extensive marketing of elephants.

With utilization through quasi-ownership and local community participatory strategies, the elephant population is now increasing in Zimbabwe, Malawi, Zambia, Botswana, Namibia and South Africa – the countries that decided not to participate in the ban.

Under the prohibition conservation strategy, the white rhinoceros, although listed in Appendix I, declined from 1 500 to 20 animals in five countries by 1960 (Simmons and Kreuter, 1989). By contrast, South Africa's rhinoceros population, which was commercialized on private farms, parks and reserves, increased tenfold during the same period.

Therefore, it is clear that sustainable management of and solutions to save the African elephant and rhinoceros do not lie in totally banning ivory and rhinoceros horn trade in all countries. Under strict control, the utilization of elephants and other economically important species through quasi-ownership, commercialization and popular participation by local communities has led to more effective conservation of wildlife. However, the success of southern African countries may be partly attributed to the availability of technical expertise and facilities for wildlife utilization schemes.

Sustainable management for multiple uses of wildlife

The real advantages of wildlife as an economical and sustainable form of land use appear in a system which offers a full range of recreational, aesthetic, nutritional and scientific uses. A system where several uses can be exploited simultaneously improves wildlife management and makes it more efficient than other competitive land-use options.

The key point here is that multiple wildlife uses enable the economic base to diversify. This is practised in several southern African countries, particularly in Zimbabwe and the Republic of South Africa. In these countries, game parks, game ranches and game farms are managed purely for wildlife or are combined with livestock and crop farming. However, wildlife is subject to many uses whereby meat can be produced sustainably and more animals can be sold as trophies for substantial amounts of money, thus allowing safari charges to be made. Indeed, the most lucrative wildlife uses in southern Africa at present are safari hunting and tourism. The land is thus used for three tiers of wildlife utilization: consumptive meat production, lightly consumptive usage for trophies and non-consumptive tourism.

Besides multiple uses of wildlife itself, multiple-use rangeland farming is also practised extensively in southern Africa. At moderate stocking levels, there is little competition between wild herbivores and livestock so that wildlife can be added to extensive livestock ranching at little cost.

In fact, combined wildlife and livestock operations are the most common form of wildlife utilization in southern Africa today. In such combined enterprises, wildlife has been found to be much more profitable than livestock, and the continuation of livestock operations does not make economic sense.

Wildlife as a land use on marginal African rangelands

The extent of marginal lands in Africa. The term "marginal lands" applies to lands whose use is limited by physical, ecological or economic factors. Thus, the meaning varies from place to place and may also change as economic factors change.

Physical and ecological factors usually include climate (characterized in Africa by insufficient rainfall and excessive heat), poor soils, soil leaching and soil erosion. Other edaphic features such as rugged terrain also characterize marginal lands in Africa. Another characteristic are low yields which cannot be appreciably raised without inputs of money or effort that are often disproportionate to the gains. Marginal lands are therefore areas that are unproductive under arable farming. The productivity of such areas depends on a wise choice of land use.

In 1990, the World Bank divided Africa into four main ecological regions, based on average annual rainfall:

- Deserts and semi-desert: 300 mm per year
- Semi-arid rangeland: 300-700 mm per year
- Arable savannah: 700-1 500 mm per year
- Tropical moist forest: 1 500 mm per year

In Africa, 8.5 percent of the total land area is classified as being under arable farming, 24 percent under forest and 19.5 percent under permanent pasture, while 48 percent remains unclassified.

Talbot *et al.* (1965) stated that 45.5 percent of Africa is "marginal" or semi-arid land with little potential for arable farming except with irrigation, while another 22 percent is semi-desert country of little value. The authors concluded that at least 30 percent of the African continent is marginal for arable farming. The World Bank (1990) maintained that semi-arid rangelands occupy almost two-thirds of Africa's total land area.

The World Bank (1990) also stated that the semi-arid regions of Africa are difficult to manage for sustainable livestock and arable farming and that, in many areas, maximum rangeland productivity for meat production has already been reached or exceeded, with resulting environmental degradation.

Wildlife versus livestock as meat producers on marginal land. Much has been written on the relative advantages of wildlife as a durable form of land use and as a source of meat in the semi-arid regions of Africa. Ecological studies have been cited to show that indigenous species (wildlife) utilize the rangeland resources (primary productivity) more efficiently than introduced livestock and that the ecosystem can support a higher total biomass of wild species sustainably. It has been shown specifically that:

- Wildlife species exist in multispecies communities, which can utilize rangeland vegetation more fully and efficiently than livestock which are usually raised in monoculture or in a mixture of a few species.
- Individual herbivores on rangelands are physiologically adapted to using their specialized foods efficiently.
- Wildlife species are often more adapted to harsh local conditions such as excessive heat and lack of water.
- Wildlife species resist disease better than their domestic counterparts.
- Wildlife have more productivity advantages, such as higher fecundity, faster growth rates and better carcass quality.
- In the fragile ecosystem of Africa's semi-arid rangelands, under an extensive management system characterized by its low inputs, wildlife has proved to be the best and optimum form of land use in terms of sustainable use of the ecosystem and of the wildlife resource itself.

Nevertheless, in the past, the advantages of using wildlife as a land use solely for meat production have been overshadowed by various technical and commercial factors: e.g. poor development of wildlife censusing, harvesting and processing methods over the years; and the numerous regulations and government subsidies and price guarantees which favoured livestock industries.

Domestication of African wildlife

Although Africa has the highest potential for domesticating wildlife, it has contributed relatively little to the world of domestic animals. The order Artiodactyla (even-toed ungulates) have provided human society with most of its important domestic animals. Fifteen out of the 22 widely used species belong to this order, which includes cattle, sheep, goats and pigs. Only two of these 15 species are indigenous to Africa, even though the continent has more than 90 species of artiodactyles.

There are two compelling reasons for giving serious consideration to the domestication of these indigenous wild species: first, the indigenous species have undergone selection by adverse local conditions, such as climate and terrain, and are therefore more likely to be fully adapted to local conditions than "introduced" traditional domestic livestock (the oryx, for example, thrives in arid conditions where cattle can barely survive); second, small ungulates such as steinbock and duiker become sexually mature at about six months of age and the females produce their first young at about one year of age. Thereafter, they have two pregnancies per year. Larger animals, such as warthog, impala, wildebeest, kudu and waterbuck, become sexually mature at one year and produce their first young at two years of age, thereafter producing once a year.

Another advantage is that indigenous herds of wildlife are immune to or tolerant of local diseases – trypanosomiasis, anthrax, tuberculosis and rinderpest, which have made large areas of African savannah uninhabitable to cattle. Although these diseases can be controlled, it often requires great expense and human resources, adding directly or indirectly to the cost of meat from domestic livestock.

However, an important question is whether wild animals will retain these desirable attributes after captivity. It is a fact that animals in captivity no longer represent their wild counterpart, since there is bound to be a degree of selection in favour of domesticated ecotypes, i.e. strains best suited to the rather abnormal environment of captivity. Further research is therefore necessary.

Until recently, the order Rodentia had also received little attention for domestication, even though it provides a significant portion of the total bushmeat consumed in the forest region of West Africa (FAO, 1979). The rabbit belongs to the Lagomorpha order, a group of animals with the special advantages of a small size, high fertility rates and short gestation periods and breeding intervals. These make them attractive propositions for rearing in captivity to supplement meat production from established domestic livestock.

Research in Nigeria by Ajayi has placed three species of African wildlife on the world's list of domestic animals, namely the African giant rat, the grass cutter and the Nigerian breed of helmeted guinea fowl. Research is necessary to bring more species into the fold for "gene conservation" and for sustainable management of African wildlife.

CONCLUSIONS AND RECOMMENDATIONS

i) Past approaches to wildlife management and utilization make it clear that a total ban on exploiting and utilizing economic species and alienating local communities from the natural resources are strategies which are inimical to sustainable management of wildlife.

ii) Wildlife management and utilization is a better form of land use on the vast marginal lands of Africa which are unproductive to agriculture.

iii) Quasi-private ownership of land and its wildlife – with wildlife utilization under strict ecological principles – and commercialization of wildlife have ensured a more effective protection, restoration and sustainable management of African wildlife. This is contrary to the old approach of public ownership which has resulted in widespread illegal hunting and the present decline of African wildlife.

iv) Multiple uses of wildlife on the same land, such as game farming tourism and safari hunting, have economically enhanced wildlife in southern Africa, and this approach could serve for future wildlife development programmes in other parts of Africa.

v) Domestication of fast-reproducing and -maturing wildlife species is a desirable approach to sustainable management of wildlife resources. African wildlife species are better adapted to their local environments and more immune to disease than traditional domestic animals. In several cases, small African antelopes are able to produce more meat than their domestic counterparts.

vi) In the local community participation projects, three distinct participatory elements were essential to success:

- the active participation of the rural communities in the projects;
- bestowal of the "appropriate" authority on the communities, or its restoration to them, so they might take vital decisions on managing and utilizing their own resources;
- distributing benefits of management efforts and resource utilization to the rural communities directly, either as cash bonuses or through the provision of social amenities.

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Conserving genetic resources in forest ecosystems

R.H. Kemp and C. Palmberg-Lerche

This paper discusses the importance of conserving the wide range of plants and animals of actual or potential social and economic importance contained in forest ecosystems. Their genetic diversity is the basis for the sustainable development and management of forest ecosystems, and it buffers such ecosystems against environmental change. The importance of including extremes of natural occurrence in genetic conservation programmes is stressed. Other subjects included in the paper are the concept of Standard Stands, conservation in tropical moist forests (especially the harmonization of logging techniques with the conservation of genetic diversity and with sustainable forest management), the use of resource inventories to assist in genetic conservation and the need for the development of national strategies for genetic conservation coordinated with other sectors of the economy.

Forests, the biological diversity they contain and the ecological functions they help maintain are a heritage of humankind. Forests and woodlands contain a large range of species of actual or potential socio-economic importance globally, nationally and locally, including wildlife species, wild relatives of important crops and trees producing wood and timber, fodder, fruits, latexes and other products. Foresters are in a key position to help ensure the conservation and wise use of these valuable resources (FAO, 1988).

Genetic diversity in forest ecosystems and variation among and between species is the basis for their adaptation to environmental stress, including the future, and possibly more extreme, effects

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of global climate change and the emergence or introduction of new pests and diseases.

Genetic diversity is, furthermore, the fundamental base for sustainably developing and improving forest resources for human use. This is an urgent need, as the expansion of human populations and ever-higher aspirations for economic development demand a more efficient use of the finite land resource and the conservation of the resource base.

Over the past decades, genetic selection and breeding, coupled with intensified management strategies and methodologies have led to greatly increased agricultural production. At its most intensive, the management of agricultural crops today involves the provision of highly controlled environmental conditions, for example under glass or plastic. The scale of forests and the life span of trees to harvestable size, relative to the unit value of their marketed produce, preclude large-scale, human changes to their environment, except at the nursery stage or in controlled propagation. Increased forest productivity therefore depends on selection, breeding and propagation aimed at matching the crop as closely as possible to its environment and end-use objectives, as well as on the maintenance of a broad genetic base to buffer tree populations against changes in the environment.

The nature of forest genetic resources

Genetic resources include the economic, scientific or social value of the heritable materials contained within and between species. The values derived from genetic resources are generally associated with the different levels of organization and diversity that exist in nature, from ecosystems to species, populations, individuals and genes (FAO, 1988). The conservation of genetic resources at the species and intraspecific levels in natural forests depends on maintaining essential functional components of the ecosystem; these may include interactions such as symbiotic relationships and interdependence between tree species and their animal pollinators, seed dispersers, etc. Research has frequently revealed hidden complexities, for example among "plant web" and "food web" systems (Gilbert, 1980; Terborgh, 1986; Whitmore, 1990).

The conservation of natural forest ecosystems is an important function of national parks and other fully protected areas and may often be compatible with other objectives such as watershed management or the protection of wildlife resources. However, the conservation of important genetic resources at an intraspecific level, between different provenances or individual genotypes, may not be adequately covered through the maintenance of fully protected areas alone, given the very limited and often accidental distribution of such areas in most countries. Depending on the distribution of intraspecific variation, which is dependent on the species' breeding and seed dispersal systems, valuable genetic resources may be lost even if the species *per se* survives through the conservation of representative ecosystems. When planning conservation activities, it is therefore essential to state clearly the objectives of conservation, giving due consideration to the various levels of diversity found in nature and outlined above (FAO, 1990). It is not necessary, nor usually possible, to conserve all levels of genetic diversity in all areas; some areas of forest may be devoted to ecosystem conservation while others may be managed to conserve intraspecific variation as part of a network of conservation areas containing selected target species or populations (FAO, 1993a).

There is inadequate information today on the variation and variation patterns of the majority of forest species. Very often, genetic differences between provenances of a species can only be hypothesized from their geographic or ecological situations (Frankel, 1970). In the absence of more reliable information, the safest practicable conservation strategy must be to conserve as wide a range of provenances as possible, with particular attention given to sampling the more extreme environmental conditions of the species'natural occurrence. Not only are the populations in such conditions likely to be genetically distinct, through adaptation to the local environment, but they may also be more vulnerable to loss through forest disturbance. A conservation strategy aimed at capturing intraspecific variation thus requires a number of conservation areas scattered over the entire range of the species, many of which will also have other objectives, such as timber production or soil and water conservation.

Management of diversity

Forests are naturally dynamic systems, subject to cyclical changes through periodic disturbance, senescence and ecological succession. Their genetic diversity, particularly in the more complex formations, results not only from the number of species present in a given area but also from successional changes. The richest areas of diversity are likely to be those including secondary forest in various stages of recovery. Depending on the forest management system and the degree of understanding of forest dynamics underpinning it, genetic diversity and specific genetic resources may be enhanced or reduced by human intervention in given areas of forest over given time periods. The most vital need in conservation is the adequate control and continuity of management to meet specified aims and to be carried out within consistent land-use plans and national forest policies. Based on a sufficient knowledge of forest composition and dynamics, management systems aimed primarily at producing timber and other forest products and services can contribute substantially to conserving a forest's genetic resources. Hitherto, particularly in the complex tropical moist forests, economic forces and market demands have imposed management systems aimed at simplifying and truncating the natural complexity and successional development of ecosystems. The growing recognition of the potential value of genetic diversity, together with rapid advances in technological means to handle and interpret large and complex arrays of data of the functional relationships in the forests, is likely to lead in the future to more varied management for diversity over a given territory, harmonized with other economic and social needs.

Every country, and to a large extent each area of forest, is unique in terms of its genetic resources and the appropriate strategy for their management. The potential contribution of each forest management unit to the overall national objectives for conserving the country's genetic resources will vary according to location; environmental conditions; species composition, size and shape; and many other factors. As mentioned above, it is neither necessary nor desirable to prescribe equal priority and intensity of genetic resource conservation to all production forests. However, sustainable forest management should, by definition, always include provisions for protecting site conditions, seed trees, seedling regeneration and advance growth of desirable species. It should do this according to management plans and prescriptions which should balance productive, protective and environmental needs.

In summary, the challenge for genetic resource conservation is not to select, set aside and guard protected areas containing genetic resources, nor to preserve seed, pollen or tissue in a seed bank. It is to maintain the genetic variability of target species within a mosaic of economically and socially acceptable land-use options, including protected areas and managed forest reserves (FAO, 1991). Such *in situ* conservation should, where feasible, be complemented by *ex situ* conservation of genetic resources of priority species.

National policy

Although effective action to conserve genetic resources depends ultimately on operations within and around specific areas of forest, such action must also be planned as an integral part of overall national development policies. This integration must embrace not only policies for forest and land use, taking account of the contributions of both the productive forest estate and the system of fully protected areas, but also extend to aspects of forest industry, trade and linkages with other sectors of the economy. With this level of integrated planning and management, the national objectives of maximizing the sustainable harvest of wood and non-wood products, protecting soil and water resources and conserving ecosystems and genetic resources can be efficiently achieved.

National strategy design must take account of the distribution patterns of species and associations in relation to their presence in other areas of forest. In some areas of production forest, prevailing needs and management prescriptions may lead to the extreme refinement of the stand composition to favour one or a few species in an ecosystem which, in its natural state, consisted of a larger number of species. If done with a full understanding of forest dynamics and the effects on the long-term functioning of the ecosystem, this action may contribute to conserving the genetic resources of those species targeted for use, at an acceptable cost to the total genetic diversity in the specific forest area concerned (FAO, 1984; FAO, 1993a; Kemp, 1992).

The conservation of genetic resources *in situ* within natural forest ecosystems may be the only possible strategy for the great majority of species in the more complex forests, such as the tropical moist forests. However, provision for *ex situ* action may be needed to complement such a strategy (FAO, 1975). This may be true if populations of target species are threatened by forest clearance, or by loss of genetic integrity through pollen contamination originating from non-native plantations.

The techniques for *ex situ* conservation are well established and their limitations well known: the recalcitrant behaviour of the seed of many high forest species, particularly those characteristic of late stages of succession in the moist tropical forests; missed opportunities for further evolutionary change in material stored in controlled conditions, such as seed banks; and the difficulties and time involved in regenerating seed lots when germination falls below acceptable limits (FAO, 1993b). Specially established *ex situ* conservation stands, if replicated under different sets of environmental conditions and appropriately managed, may safeguard broad genetic variation within the species concerned while providing a source of material for breeding programmes to serve production objectives (FAO, 1975).

Although it is normally assumed that tree breeding programmes will reduce genetic diversity, they may be designed to maintain variation within populations and even, by multiple population management, to increase the total genetic variation (Namkoong, Kang and Brouard, 1988). Nevertheless, strategies for *in situ* conservation in natural forest ecosystems deserve the most urgent attention, particularly to take advantage of the conservation contribution of the production forests and to seek opportunities for combining the conservation of genetic resources of economically important target tree species with the protection of the gene pools of associated species, for example those providing non-timber products and benefits important to rural people.

Genetic structure

Management systems aimed at combining production objectives with the conservation of genetic resources require some understanding of both forest dynamics and the genetic structure of species and populations. Understanding genetic diversity and the patterns of distribution of genes within and between the target populations is critically important for efficient conservation strategies, both *in situ* and *ex situ*. The genetic structure of a species results from mutation, migration, selection and gene flow between separate populations, and it is strongly influenced by the genetic system, embracing the breeding system and dispersal mechanisms for pollen and seed. Information on the genetic structure of forest trees is very limited and, for most tropical species, it is non-existent. Evidence from provenance trials of temperate and tropical tree species, allied at times to isoenzyme analysis, has nevertheless shown that high genetic variation is normally present both between and within populations. The rate of out-crossing is also generally high, although inbreeding and even apomixis have been reported for some tree species and for isolated individuals of such species, especially in the tropical moist forests (Bawa, 1974; Bullock, 1985; Bawa and Krugman, 1991; Janzen and Vasquez-Yanes, 1991).

Knowledge of the genetic structure has implications for the location, number, size and management of *in situ* conservation stands and for sampling for *ex situ* conservation. However, even without such knowledge it seems likely that, for out-crossing and widely distributed species, a few populations in each major geographical zone may be sufficient to conserve much of the genetic diversity (National Research Council, 1991). Genetic conservation need not cover all populations, but those in different ecological conditions are more likely to contain different genotypes, genes (alleles)[1] and gene frequencies. By targeting ecosystems at the extremes of a species' natural distribution range, with an effective population size of a few hundred individuals each and a total population of a few thousand, sampling will ensure a high probability for capturing most alleles (Namkoong, 1991). In the more complex and species-rich tropical forests, in which mature individuals of target species may be scattered at a low density of only one or less per hectare, harvesting or other causes of loss could alter the levels and patterns of out-crossing or inbreeding within the population, possibly having detrimental effects on fertile seed production and on the longer-term viability of the population. The effects might not necessarily be negative, since removing closely related individuals could encourage wider out-crossing, with possibly beneficial results. In other cases, an existing soil seed bank may supplement the regrowth after a first harvesting intervention. However, the more extensive and severe the disruption, the greater the likelihood of adverse effects; the possible impacts must therefore be considered in forest management prescriptions, based on existing knowledge and subsequent monitoring of their effects.

[1]The structural and functional unit of inheritance is the *gene*, which is the physical entity being transmitted during the reproductive process and which influences hereditary traits among the offspring. Genes can exist in different forms or states; these alternative forms of a gene are called *alleles* (FAO, 1993a).

Standard Stands

Tree species of proven economic value that are already used in large-scale plantation programmes are frequently subjected to genetic improvement programmes, which include the selection, breeding and propagation of desirable individuals. Even when multiple population breeding programmes are planned to maintain or enhance genetic diversity of the species in use, some elements of the diversity in the original wild populations may be incidentally lost. Sustainability in long-term plantation and tree improvement programmes may ultimately depend on retaining access to the original wild populations, left to evolve and adapt to changing conditions. These original populations, furthermore, constitute a standard against which others, of different provenance or the result of selection or breeding, may be judged.

Increasing human populations and higher material standards of living imply a more intensive use of land and natural resources, leading to a progressive reduction of natural forest areas. Although some stands may be left intact, for example in national parks or on inaccessible or difficult terrain, these are unlikely to represent the original populations adequately. In Finland in the mid-1950s, such considerations led to the concept of a system of Standard Stands within areas of natural forest. The original idea was to establish a network of stands of each of the most important tree species, representing the principal ecological areas throughout the country (Hagman, 1971). The stands chosen were neither "plus" nor "minus" but rather average for the area and large enough to yield a good supply of seed as well as to ensure good, within-stand pollination without the risk of excessive inbreeding. The minimum stand size chosen for species such as *Pinus sylvestris*, *Picea abies* and *Betula* spp. was 1 ha, with a 100 m surround area and a total area of 5 to 6 ha if possible. Detailed site descriptions and mensuration data were recorded together with records of seed collected from the stands and its distribution for experimental purposes or operational planting. The overall purpose of the system was to conserve the genetic identity of specific provenances of priority species for as long as possible, with propagation based on natural regeneration of each stand or, alternatively, on replanting using seed collected within the stand.

The Standard Stand approach developed very well owing to the relatively simple composition of the natural stands, the advanced state of Finnish forestry and the high level of effective management in both state-owned and private forests. In principle, it should be possible to introduce a similar system in other countries. The possibilities are most evident in countries in the temperate zone and appear to be most problematic in tropical countries because of complex species compositions and the inadequate knowledge of ecosystem dynamics. Nevertheless, where recognized plantation species are found in sufficiently large natural stands that are representative of their original distribution, the establishment of Standard Stands, under effective control and with long-term security of tenure, should be considered. The Central American pine forests constitute an example (Kemp, 1973). The work already undertaken in the provisional delineation of provenance regions and proposed conservation stands in the natural forests of *Pinus caribaea* and *P. oocarpa*, for example in Honduras (Robbins and Hughes, 1983), provides some scientific basis for developing a Standard Stands network there.

Other recognized tropical plantation species that occur in relatively simple and largely monospecific stands – including species of other tropical pines, teak, *Gmelina* and eucalyptus – might be amenable to this approach, given sufficient knowledge of their natural distribution and adequate levels of effective protection and control. The commercial and environmental importance of trees in arid and semi-arid regions makes the conservation of their genetic resources a high priority, requiring urgent action in the context of widespread and increasing deforestation and degradation (Palmberg, 1981; 1986). However, opportunities to apply the Standard Stand approach to species in these areas have already been limited in many cases by severe fragmentation of the natural forests and woodlands and by the influence of human societies in the selection and undocumented distribution of especially those species which have long been recognized for their nutritional value. For species such as *Gliricidia sepium*, originating in Central America, or *Faidherbia albida* (syn. *Acacia albida*) from Africa, conservation will increasingly depend on *ex situ* action based on information gained through international provenance research and field trials, although all opportunities should be taken to conserve remaining representative natural stands *in situ*, harmonizing conservation with sustained use; and ensuring that non-local genetic materials, which might hybridize with the species or with the local provenance, are not introduced without demonstrating their superiority or adequately safeguarding the genetic integrity of the local gene pool.

In the case of Standard Stands, as for genetic conservation in general, meticulous documentation of the material to be conserved is essential. The development and maintenance of computerized databases are important aids to such genetic conservation efforts.

Tropical moist forests

In the more complex tropical forest formations, particularly the tropical rain forest, where close to 300 species of trees have been recorded on a single hectare in Peru (Whitmore, 1990), genetic resource conservation in the context of sustainable development presents particular problems. The importance of *in situ* conservation action and the development of systems of fully protected areas have already been recognized.

Because of the ever-increasing pressures on land and forest resources and the limitations on the location and extent of protected areas, the contribution of production forests to genetic resource conservation is increasingly and critically important. The multiple roles of natural forests are recognized for their social and environmental benefits as well as for production. The continued provision of wood and non-wood forest products, and even the long-term functional efficiency of the ecosystem itself, may depend on safeguarding an appropriate range of both specific and intraspecific genetic diversity of its component species.

For effective sustainable productive forest management, data are needed on the composition of each of the main forest types as well as on the silvicultural characteristics of the principal species and of those which may compete with them at various stages of their development; such data include regeneration behaviour, growth rates, response to canopy opening, logging and silvicultural operations. Management for the *in situ* conservation of genetic resources of the principal tree species requires the same basic data on ecology and autecology as do silvicultural interventions, but with greater emphasis on breeding systems and genetic structure. The scientific basis for conservation depends essentially on studying and interpreting taxonomic information on genetically determined differences and affinities, their patterns of natural distribution and their ecological bases.

Very often the only data available are from standard forest inventories, but these assess stocks of harvestable timber, not usually the actual composition or condition of the forest. Since a high proportion of the cost of inventory operations is spent in the access to and support for field work in the forest, the cost of collecting additional data to serve as a basis for conservation activities would be relatively low. Surveys of non-wood forest products and of variation patterns in the floristic composition of the forest can provide the basis for genetic conservation strategies, incorporating both the principal economic species and those providing other benefits. Non-timber forest products commonly represent the most direct evidence of forest value in the eyes of the local people and often cannot be substituted by establishing forest plantations; sustainable *in situ* management of these resources is therefore a key to securing local support for conservation.

Resource inventories

For the forest inventory to serve its full purpose in assisting the conservation of forest genetic resources, it must provide data which can be used to assess the relative conservation value of a given area of production forest, for example the distribution range of selected species or forest types in relation to other reserved and protected areas. This should help determine the minimum number and most efficient combination of conservation sites to cover the target species, populations and plant communities adequately. Variation in the environment and in the plant community as a whole may indicate possible patterns of intraspecific variation in target species. The degree of precision in surveying resources providing non-wood forest products may relate to the likely levels and methods of harvesting: if the products are to be freely gathered, information will be needed principally on regeneration potential and levels of sustainability, so that broad qualitative assessments may be sufficient.

The efficiency and cost-effectiveness of the inventory process depend on the planning stage where the appropriate range of botanical, ecological and sociological expertise, both in survey formulation and implementation, must be included. This should include expert involvement in designing the systems of data capture, handling and analysis. The widespread availability of computing capabilities for data handling and analysis has transformed the possibilities for understanding forest composition and genetic diversity patterns. Simulation of the variability and complexities of population distributions using stochastic models, such as those designed to measure the average number of occurrences in a given area, may be used to reveal variability patterns and thereby help select priority locations for conservation. Geographic information systems (GIS) can be an important aid in defining and interpreting species distribution patterns in relation to environmental variables and vegetation types. The design and management of appropriate database systems should aid the synthesis of all available relevant information on forest composition, species distributions, phenology of flowering and fruiting and other relevant data from various sources. Within the production forests, the network of permanent sample plots may be used for phenological studies and basic research observations.

Harvesting of timber and genetic diversity

In many tropical production forests the harvesting of timber is currently the only large-scale management intervention. Unless carefully planned and controlled, harvesting may severely damage stand structure, site capability and regeneration. Nevertheless, based on a sufficient understanding of ecosystems and ecological processes, logging and timber extraction can be used to assist in the conservation of genetic resources of the principal tree species. Theoretically, selective logging could be planned to maintain a balance between the areas of forest devoted to the different stages of ecological succession in a country or over an ecological region, thereby allowing the maximum total genetic diversity to be conserved of both pioneer species and those characteristic of later successional stages. This might be achieved in various ways: by localized clear-cutting at long intervals, allowing each newly felled area in turn to revert to the mature, climax condition; by the careful opening of small gaps through the removal of individual trees; or by various possible intermediate patterns and harvesting intensities. However, frequent repetition of even low-intensity harvesting in the same forest area may have an adverse effect on the breeding populations of the slower-growing species by altering the number and distribution of mature reproductive individuals in such species that are present before the next felling; the effects of interventions must therefore be continuously monitored.

The retention of enough seed trees of good phenotype, well distributed through the stand, is important for future sustainable productivity and for genetic resource conservation, particularly where there are inadequate levels of established seedlings and advance growth of desirable species, and where there is an inadequate soil seed bank of target species. The presence of residual large trees after the main harvesting operations presents some problems in subsequent management of the stand if they are so numerous as to compete with the next crop or are subsequently harvested with related extraction damage. Nevertheless, the loss in immediate production is slight compared with the dangers of progressive deterioration of the genetic quality of the population through reliance for regeneration on the residual, smaller individuals, should these prove to be of inferior genetic quality.

The seedlings of many tree species which characterize the later stages of succession depend for successful regeneration on surviving for long periods under the forest canopy rather than on the rapid colonization of gaps or the germination of seed dormant in the soil. Seedlings are particularly vulnerable to damage by logging while harvesting aggravates the adverse impacts on such species by opening the canopy extensively and suddenly, thereby drastically altering the environment in favour of conditions preferred by fast-growing pioneer species. Since the heavy-seeded climax species most often depend on animals for seed dispersal – a system which prevents localized seed concentration and loss through predation – the disruption of animal populations caused by logging may have further adverse impacts on these species. Quite small areas of unlogged forest, within or adjoining logging concessions, may be critically important to survival within the area of keystone animal species (Johns, 1989) and thus to the forest's long-term sustainable productivity.

The increasing use of heavy mechanical equipment for timber harvesting has severely harmed many tropical production forests. Where the effect on advance regeneration is accidental, it tends to be distributed over all tree species quite randomly, so the impact on the genetic resources is indiscriminate (Johns, 1988). However, the impact on already rare species subject to selective logging will be severe through reduction of the future breeding populations. Where market demand is very selective, exclusive concentration on extracting the best phenotypes of the most desirable species is likely to result in progressive deterioration in the overall genetic quality of the stand, unless specific silvicultural treatments are applied to favour regeneration of the species under use. Yet, with forward planning of harvesting allied to strict controls on road construction, logging plans, timber marking, felling and extraction, the harvesting operation can be used to promote genetic resource conservation, as outlined above. Furthermore, even the narrower range of total genetic diversity that may result from repeated harvesting and refinement operations will be greater than if the same area were converted to a forest plantation, and certainly much greater than if it were to be changed to alternative forms of land use.

The most severe impacts of logging on genetic diversity result from human intervention after harvesting, through agricultural encroachment or fire. While some drier forest formations are adapted to survive periodic burning and may be fire disclimax communities, in the more complex moist forests fire will severely reduce diversity; in extreme cases, whole populations of regrowth may be lost through fire following the felling of all adult trees of a species in the area concerned.

Silviculture

For *in situ* conservation, natural regeneration is clearly preferable and is likely also to be the cheapest option for sustainable management of production forests, provided that it can be confidently assured. In practice, it has proved to be one of the most difficult and uncertain aspects of management in a wide range of forest types, especially in tropical moist forests. Monocyclic, or shelterwood, systems relying on seedling regeneration have been tried extensively in all tropical regions but they have encountered severe problems, particularly with climber infestations and their failure to induce adequate regeneration of the principal economic species. Increased demand and a wider acceptability of lesser-known species, leading to more intensive felling operations, have tended to favour pioneer or near-pioneer species – including some with light, pale, general-purpose marketable timbers – at the expense of the slower-growing heavier hardwoods. The repetition of frequent felling and short rotations is likely to harm severely the breeding populations and genetic resources of these latter species, which are characteristic of later-stage and mature forests.

Polycyclic systems relying on advance regeneration can theoretically incorporate mature-phase species, with longer felling cycles for such timbers; therefore, they can conserve a broader spectrum of genetic resources in terms of species composition. However, if selective felling repeatedly removes the fastest-growing and possibly most desirable individuals, there is some danger of dysgenic effects within populations of harvested species, leaving less vigorous and perhaps defective stems to regenerate. Moreover, without deliberate interventions to favour the growth of the immature trees of the desired species, stand quality may deteriorate. Such damage may be avoided through responsible management and harvesting practices, but implies skilled tending and well-planned and controlled harvesting practices.

Silvicultural operations – particularly refinement operations or liberation thinnings to favour certain species and individuals – can be strongly discriminatory and can therefore negatively influence genetic diversity at the species level, leading to a decrease in overall diversity. Depending on the information, skill and investment applied, they may also be used to maintain diversity and to restore the genetic resources of selected species. A combination of logging operations and silvicultural treatments may be used to develop and maintain a mosaic of different stages of ecological succession as well as of different tree populations, including where appropriate the delineation of "core" zones, devoted primarily to conservation, and "buffer" zones of more intensively managed production forest. The efficiency of such zoning would depend on the design of a national network of conservation areas, embracing both the fully protected reserve system and the production forests and extending across the natural range of the principal species.

National strategy

Effective action to conserve forest genetic resources requires coordination both within the forestry sector, including industry and trade, and outside. Coherent incentive systems for sustainable forest management are required at every level within the country and at all points in the chain, from the forest to the national and international markets. Necessary conditions include fair trading practices, appropriate investment in local processing, marketing assistance and maximum recovery of the value of the products in the country of origin and the channelling of part of the profits back into the forest in support of ecologically and economically sound forest management.

An urgent task is to prioritize target species, populations, areas and activities for the conservation of genetic resources in each country. This must take account of needs for *ex situ* as well as *in situ* action as components of a coherent programme, in accordance with the national policy and the biological characteristics of target species. Specific management systems and the level of priority to be assigned to conservation objectives must be determined for each forest or management unit to achieve an appropriate balance within the national forest estate as a whole, giving due weight to both socio-economic and ecological objectives. The scale and complexity of the data needed for sustainable forest management to meet both sets of objectives require coordination through a national data centre, with appropriate international links, to facilitate and stimulate the collection of information and to make it readily accessible in a suitable format. The formulation of a national strategy for the conservation of forest genetic resources is the most appropriate means to ensure the effective use of available national resources, including forest lands, as well as to secure opportunities for regional and international cooperation.

In all aspects of forest management and genetic conservation, the failure to comply with prescriptions and conditions has frequently damaged the growing stock and, particularly, its regeneration capacity. For both sustainable management and genetic conservation objectives, it is essential to monitor operations closely both to see if they conform with the national strategy and to assess their ecological, silvicultural and socio-economic effects.

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Climate change and sustainable forest management

D.C. MacIver

Climate, its variability and changing structure, plays a major role in the growth, development, migration, succession, mortality and regeneration of forests. Historically, climatic information was usually incorporated into forest management decisions locally or regionally, but little attention was paid to the impact of the global climate. The potential change in the global climate (the trend towards future warming) threatens forest sustainability and endangers known management practices. Therefore, it is essential that a climate plan be developed as an integral part of sustainable forest management, developing improved regeneration and protection prescriptions to adapt to the change. The reasons for such global change include increased releases of "greenhouse gases", such as carbon dioxide, methane, nitrous oxide and ozone. Since the turn of the century, human activity seems to have been the major source of further carbon dioxide releases: land-use change, deforestation and fossil fuel burning. The use of global calculation models (GCMs) is discussed in this paper.

A climate plan for sustainable forest management comprises two key elements: forest climate management and greenhouse gas management.

Forest climate management includes the following: identifying shifting seed zones; pollen flow and contamination; site modification technologies; forest climate manipulation practices (physical alteration, breeding programmes, conserving biodiversity); and enhanced protection. Greenhouse gas management should focus on altering pools and fluxes of carbon, methane and nitrous oxide and on the continuing role of forests in reducing atmospheric concentrations of these gases.

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INTRODUCTION

Forests and foresters are constantly changing. Forests are engaged in the complex act of adaptation with one species followed by another, either gradually through natural succession or rapidly by climate-based or other disturbances. In response, foresters have developed forest management actions designed to sustain and, in some cases, enhance the social and economic benefits derived from the forest sector.

Forests are able to protect themselves against many threats to their growth and development, including the ability to regenerate after severe disruptions. Many forest management actions aim at taking advantage of this buffering and renewal capacity of the forest. For example, today's boreal forest has evolved from a series of disturbances, especially fire, into a mosaic of species and age classes. Similarly, silvicultural practices attempt to develop hospitable site conditions for regeneration after timber harvesting. Forest managers have developed prescriptions, by species and site condition, for successfully renewing managed forests and protecting unmanaged forests.

Climate, its variability and changing structure, plays a major role in the growth, development, migration, succession, mortality and regeneration of forests. Historically, climate information was usually incorporated into forest management decisions locally or regionally, with little attention given to the impact of the global climate.

The potential change in the global climate poses a new threat to forest sustainability and jeopardizes the forest management practices based on current and historical climate variability. A climate plan should be developed as an integral part of the sustainable forest management process. For example, meteorologists tend to view the atmosphere as a subdivision process from the global to regional to local scales; however, foresters tend to aggregate from the tree to the stand and then to the forest level. These opposite temporal and spatial approaches need to be assessed and integrated carefully. The biological storability of wood on the stump is finite, and the forester, together with the meteorologist, should develop improved renewal and protection prescriptions reflecting the opportunities under a changing climate.

Indications of future global warming significantly influence all forest management activities and will affect many decisions taken at the operational site level – the selection of species, site modifications, the preservation of the biological heritage, enhanced protection strategies and the incorporation of new technologies – in the aim of maintaining a sustainable forest sector and protecting ecosystems.

THE CLIMATE CHANGE ISSUE[1]

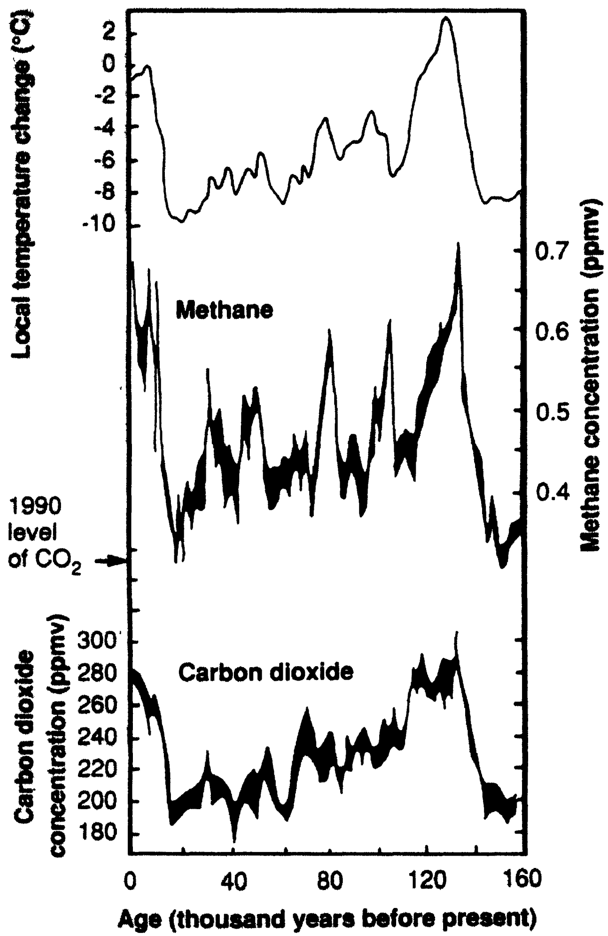
The atmosphere is a dynamic system that is constantly changing. Volcanic activity, solar orbital shifts and changes in the natural greenhouse effect are some of the forces that have caused variable climates throughout the earth's geological history. For example, in the Middle Ages a warm and benevolent climate, lasting from about AD 900 to AD 1200, known as the Medieval Optimum, permitted human habitation to extend to normally harsh areas such as Greenland. In the thirteenth century, a 600-year period of pronounced cooling occurred which was known as the "Little Ice Age" (Easterling, 1990). Biotic resiliency needs to be assessed and incorporated as a basic ingredient into sustainable forest management strategies. Tropical forests, for example, have adapted to a number of severe disruptions, such as fire, drought, insects, disease, hurricanes and land-use changes, and continue to support intensive biodiversity, although in an altered state. Naturally induced change has occurred and will continue to occur while forest ecosystems will continue to adapt to changing conditions when tolerable thresholds are exceeded or will recover if the change is minor.

The balance of heat within the atmosphere is the difference between the incoming and outgoing radiation between the sun and the earth. The outgoing, or infrared, radiation on its return journey to space is intercepted by clouds and greenhouse gases such as carbon dioxide, methane, nitrous oxide and ozone. The strong relationship between temperature change and two greenhouse gases, carbon dioxide and methane, is shown in the Figure (Hengeveld, 1991). This proxy climate data source reinforces the correlation that exists between increasing greenhouse gases and temperature change and also highlights the elevated level of carbon dioxide in the atmosphere today (1990) compared with the last 160 000 years.

Since the turn of the century, human activities appear to be the major additive source for carbon dioxide releases into the atmosphere. Land-use change, deforestation and fossil fuel burning add to the natural balance between the releases and the removals of carbon to and from the atmosphere. Carbon dioxide concentrations in the atmosphere have increased by 11 percent over the last 30 years, suggesting that at least half of the anthropogenic emissions remain in the

[1] Climate change is also discussed in the paper by Ciesla, p 131

FIGURE
The relationship between temperature change and the greenhouse gases methane and carbon dioxide



Source: Hengeveld (1991), adapted from Houghton (1990b).

atmosphere. "In other words, the natural system appears willing to forgive a part of the human interference, but only part" (Hengeveld, 1991).

Forests are particularly fragile when their natural thresholds have been exceeded, with the result that change becomes inevitable. The cost of restoring ecosystems in some countries may prove insurmountable compared with the accelerated development of new adaptive technologies, the introduction of new species and site modification costs.

Global forces play a significant role in the increase of greenhouse gases in the atmosphere. Social and economic pressures to enhance the standard of living in many countries, together with a projected doubling of the world's population within the next 50 years, will probably result in increasing emissions into the atmosphere. There is considerable uncertainty concerning future rates of greenhouse gas increments at a time when political and technological actions are difficult to predict. However, it is reasonable to conclude at this point in time that human activities have changed the composition of the atmosphere, and these changes, by exceeding the buffering capacity of earth's ecosystems, will have a major impact on the forest ecosystem. Forest management practices need to adapt to this change.

Global climate change towards warmer climates will not be uniform across the earth's surface. Within the global circulation system, large amounts of heat and moisture are transported from equatorial regions towards the poles and vice versa. This interaction of air masses with the earth's surface topology creates regional climate patterns which display a unique convergence of energy and moisture to support biotic activity. If the climate changes slowly over time and space, then forest ecosystems will have the opportunity to adapt; however, the realities, with increasing greenhouse gas emissions, point to a rate of change that will exceed the natural adaptive abilities of the forest. In cases where the forest is also subject to a multiplicity of stresses, such as acid precipitation, air pollution and higher ultraviolet radiation, accelerated rates of forest degradation, decline and alteration can be expected.

A number of global circulation models (GCMs) have been developed to understand the changing climate better, especially with elevated levels of carbon dioxide. Increases in global mean temperature in the range of 1.5 to 4.5°C are based on a doubling of carbon dioxide levels and exceed previous historical rates. Global precipitation is expected to increase slightly but the net effect will be a significant increase in evaporation rates in the middle latitudes of the Northern

Hemisphere. These models have attained intellectual credibility but there is still a critical need to examine the interactions with the forest ecosystem during the transition to a doubled carbon dioxide state. The Canadian Climate Centre's GCM projects global temperature increases of 3.5°C and evaporation and precipitation increases of 3.8 percent, which far exceed the optimum thermal and moisture ranges for many species (MacIver, 1989). Other GCMs have, in some cases, significantly higher values but all agree that the future climate direction is towards global warming. This conclusion alone is sufficient to shape future forest management actions.

SUSTAINABLE FOREST MANAGEMENT

The impact of a warmer climate on sustainable forest management will be most noticeable at the boundaries of the ecotones, alpine species, unique species niches and populations without the genetic diversity to adapt. In other words, all forest species will need to adjust while retreating species are replaced by other species. However, in many locations, including North America, the northward expansion is limited by poor soil conditions. The ability to sustain this forest sector will depend on increasing the productivity of the current forest land base instead of expanding into new and marginal landscapes.

Many countries rely heavily on their forest resource sector to support development programmes. For instance, the value of exports in $CAN billion for the following countries were: 2.0 for Indonesia, 1.2 for Brazil and 0.5 for Chile in the tropics and subtropics; and 16.9 for Canada, 8.7 for the United States, 2.5 for Austria and 7.2 for Finland (FAO, 1993).

Wood products are important in these and other national economies, as are the multiple benefits derived from wildlife, recreation, soil conservation, catchment protection, the conservation of genetic resources, wilderness areas and cultural values of the forest.

Wood is also an integral part of any energy conservation programme for building and construction and the long-term storage of carbon. Wood can provide a renewable energy supply as a substitute for the use of fossil fuels. In some countries, wood is the only domestic fuel. Any changes in the climate that might affect the sustainable output of goods and services from the forest must therefore have a major impact on every country and every region.

THE CLIMATE PLAN

Various studies have highlighted the sensitivity of the forest sector to a changing climate, especially in temperate and boreal regions. The impact of climate change on the forest ecosystem must be evaluated holistically as human activities have a dominant influence on the conservation and use of this ecosystem. In many countries, forest management actions tend to be mission-oriented towards one or two goals. However, the new threats of a changing climate will affect all components of the forest ecosystem.

Forest management actions can alter the forest climate and the greenhouse gas balances between the forest ecosystem and the atmosphere. These balances are the major elements of a climate plan for sustainable forest management.

Forest climate management

Forest canopies serve as an interception layer between the atmosphere and the forest floor. Compared to adjacent "open" areas, the forest can regulate the exchanges of energy and moisture, thus stabilizing and protecting the thermal and moisture regimes within the rooting zone. Lower maximum and higher minimum temperatures as well as reduced moisture receipt at the forest floor characterize forest climates. Understandably, different stand structures and species compositions can significantly expand or contract the differential in heat and moisture between closed forest and open environments. Moreover, the transition climate near forest edges provides modified climate regions for enhanced regeneration and moisture conservation, especially in boreal forests. With global warming, this differential is expected to increase with open areas warming faster than the closed forest. Under these conditions, the regeneration of trees and shrubs into these open sites will come under increasing climate stress and may be in jeopardy.

A first priority for forest management should be to improve global observations and understanding of the vertical and horizontal structures of forest climates. Without this knowledge, the forest manager will be ill-equipped to develop new adaptive practices for forest renewal, production, protection and conservation under a changing climate. The forest manager can accelerate or slow down the rate of forest climate change: for example, forest clearing rapidly creates open climate conditions; selective tree harvesting retains the forest canopy and a modified forest climate.

Foresters can genetically alter the species or modify the site, or both. Local or regional management decisions can dramatically alter the forest climate and hence the forest's buffering capacity. Plantation management and agroforestry allow for greater forest climate control by designing the new forest within future climate orientations. When using selected genotypes and intensive cultural practices with short-rotation woody crop management, care must be taken to ensure that yields are sustained, biodiversity is conserved and the risks associated with long-rotation climate exposure are reduced.

The need to use timber resources at a time when other ecosystem partners advocate greater natural forest conservation will tend to lead to a partitioning of the timber land base into areas devoted to "farmed" forests and other areas reserved for multiple uses and maintaining a quality environment. This level of intensive or élite forest management is high in some countries and indications are that more countries need to do the same.

Numerous examples of static, not dynamic, scenarios of forest migration have been developed by superimposing thermal and moisture isolines over ecotone boundaries for today's climate and then projecting where the new forest will be under a changed climate. For species that are particularly sensitive to climate extremes during their physiological life cycle, these scenarios may have some validity after extreme disturbance. However, in many countries, management practices aim at manipulating the local climate for the health, productivity and renewal benefits of the forest. This ability to manipulate the forest climate possibly to delay or reduce the effects of global warming is an important adaptive management strategy.

Whether abrupt or gradual, potential changes in the forest climate need to be evaluated carefully as part of the sustainable forest management plan. A first stage in this process will be to establish forest climate stations above and within the forest to detect differential change between open and closed forest climates.

Site modification technology is used extensively in many countries to enhance crop protection against hazards such as frost, drought and wind. Likewise, tree breeding programmes are designed to improve the performance of genotypes and their tolerance for such hazards. However, under a changing climate, it is essential to improve understanding of pollen and gene flows. For example, the selection of "drought-proof" families within the variability of today's climate is a sound "preparedness" strategy for tomorrow's climate. Basic genetics and tree physiology will be one of the cornerstones of sustainable forest management.

Forest adaptation results from a complex series of events: the displacement of seed zones; pollen flow and contamination; the translocation of seed and seedlings; biodiversity; and the physical alteration of the sites. Climate-based agents for mortality such as fire, insects, disease, extreme climate events and air pollution will also accelerate forest adaptation rates. Human needs and land-use change may be the greatest disruptive agents. This cumulative threat, locally and regionally, again emphasizes the need to develop adaptive forest management strategies, including a climate plan for all operations.

Greenhouse gas management

The process of photosynthesis removes carbon dioxide from the atmosphere and converts it into woody tissue. Forests alone will not reverse the increase in carbon dioxide in the atmosphere; however, they are part of the solution to the problem.

Forests can sequester carbon in woody tissue (Houghton, 1990a; Grainger, 1990). Soil carbon pools represent a particularly large sink and can potentially sequester and store additional carbon from the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) reported that the world's vegetation and soil store 550 and 1 500 gigatonnes of carbon, respectively (Houghton, 1990b). Alterations in these pools and fluxes as a result of management actions should be accounted for. Carbon management of all forest ecosystem components – roots, soils, aboveground biomass, forest floor and understorey vegetation – should be an essential part of all forestry operations.

Tropical forests are generally regarded as a net carbon source whereas temperate and boreal forests are a net sink. Because of human activity, the tropical forests contribute carbon to the atmosphere following deforestation, biomass burning and the oxidation of organic matter in the soil. Deforestation has increased to an annual rate of 15.4 million ha between 1981 and 1990 (FAO, 1993b), mainly by shifting cultivators, and is expected to continue to increase during the foreseeable future (Myers, 1991). Population pressure and associated socio-economic needs will continue to deplete and degrade the tropical forests.

There is need for a global carbon inventory that includes natural forests, plantation forests, agroforests and urban forests and their subsequent carbon replacement by forest or other crops. It may be more meaningful to calculate the net carbon balances over time by land unit, not crop type.

The ability to calculate carbon contributions logically derives from existing timber volume inventories. A recent study by Sedjo (1992) has used data from FAO to confirm that northern temperate forests are a large net sink almost equivalent to the median value for tropical forest clearing emissions (Detwiler and Hall, 1988).

The disturbance of any forest ecosystem by windthrow, wildfire, insects, disease, extreme climate events or air pollution will further contribute to greenhouse concentrations in the atmosphere. Each of these results from direct atmospheric hazards or indirect climate-based processes, with fire receiving the most attention because of its threat to human life, to security and because of the economic loss it causes. Climate change is expected to increase the severity and duration of wildfire and outbreaks of pests as stress increases on ecosystems adapting to change. In many countries, the total burned area exceeds the annual timber harvest. Enhanced protection technologies will be another cornerstone for sustainable forest management.

Reforestation and forestation are possible scenarios involving all countries to increase the amount of wood volume and carbon stored within the global forests. In a number of countries, the decision to reforest and forest is based on many factors that limit the forester's ability to replace and expand the existing forest land base. Land that is being taken out of food production in temperate regions may offer some scope for the expansion of forest, and there may be land available in the tropics and subtropics for forestation and the planting of trees in association with agriculture. Furthermore, tropical forests have lower forestation costs than those in temperate and boreal regions. However, precise costing of the multiple benefits of environmental, human, spiritual, ethical and economic values associated with forests needs to be evaluated. All indications are that forest management must be more intensive and extensive. For example, the introduction of genetically improved species will alter the costing balances. Tree breeding programmes have demonstrated a significant improvement in productivity and carbon sequestration, thereby reducing the land base requirements.

Forest wetlands and biomass burning contribute to increasing global methane emissions to the atmosphere. Further increases in methane can be expected from future land-use changes associated with human activity. Fertilizers, especially ammonia-based, will contribute to the nitrous oxide increase in greenhouse gases. In both cases, greenhouse gas management will become an increasingly important component of the climate plan for sustainable forest management.

SUMMARY AND CONCLUSIONS

The climate, forests and foresters are constantly in a state of change. Recently, human activities appear to be accelerating the changing climate towards global warming. The consequences are expected to be severe where social and economic structures depend considerably on the forest sector. Foresters need to develop a climate plan for sustainable forest management: forest climate management and greenhouse gas management are essential ingredients in the climate plan for a sound manipulation of the energy, moisture and gaseous exchanges between the forest and the atmosphere. All indications are that tree breeding programmes, intensive forest management plus enhanced protection strategies will need to be increased under a changing climate.

The first priority should be to improve our global observations and understanding of the vertical and horizontal structures of the forest climate, by species and site type. Forest adaptation strategies should include research on the identification of shifting seed zones; pollen flow and contamination; translocation of seed and seedlings; site modification technologies; forest climate manipulation practices; conservation of biodiversity; socio-economic impacts on forest populations; and enhanced protection strategies. Greenhouse gas management should focus on altering pools and fluxes of gases such as carbon, methane and nitrous oxides, and on the contributing role of the forest in reducing atmospheric concentrations of these gases.

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Ensuring sustainability of forests through protection from fire, insects and disease

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Fire, insects and disease help bring about change and are integral to forest dynamics. However, they can disrupt the flow of goods and services from forests by affecting tree growth and survival, water quality and yield, biodiversity, forage for domestic animals and recreation. Thus, measures to protect forests from fire, insects and disease must be an integral part of sustainable forest management. This paper discusses the role of fire, insects and disease in plant communities, the factors that influence the occurrence of these agents and their impact on sustainable forestry. Measures that can be taken to reduce losses from fire, insects and disease through the development of integrated forest fire and pest management programmes are outlined.

INTRODUCTION

Forests are dynamic systems that are continuously changing. Sometimes the change is slow and hardly noticeable. At other times, it is sudden and dramatic. Fire, insects and disease are integral parts of forest dynamics. However, under certain conditions, they adversely affect the flow of goods and services that forests provide. They can affect tree growth and survival, wood quality, water quality and yield, wildlife habitat, recreation, scenic values, forage for domestic animals and cultural resources. Consequently, measures to protect forests from fire, insects and disease must be integral to forest management if sustainable levels of goods and services are to be assured.

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FOREST FIRE

Throughout human history, fire has been regarded as a strong ally and dreaded enemy. Fire provides a source of warmth and a means of cooking food. Primitive tribes used fire to drive game when hunting. Fire is used to clear land for crops or to improve forage for domestic animals. On the other hand, a wildfire raging out of control can quickly destroy natural resources, property and human lives.

The role of fire in plant communities

Fire is one of the natural forces that has influenced plant communities over evolutionary periods of time (Mutch, 1970). In semi-arid regions, where fires are frequent, forests and woodlands have evolved with adaptive traits to ensure survival or to enable them to compete with less fire-tolerant species.

In western North America, the open character of *Pinus ponderosa* forests results from natural fires. Mature trees have thick bark which enables them to survive ground fires. Ground fires keep combustible fuels at low levels and prevent hotter, more destructive fires. Without fire, less fire-tolerant species such as *Abies* sp. appear in the understorey and eventually dominate the stand (Fowells, 1965). Similar relationships have been documented for *P. kesiya*, *P. merkusii* and *P. roxburghii* in Asia (Goldammer and Peñafel, 1990). Fire also enables *Pinus oocarpa*, an indigenous pine of Mexico and Central America, to compete with broadleaf vegetation. It has two adaptive mechanisms; serotinous cones, which release seeds only after exposure to high temperatures, and saplings, which can sprout from the roots after the original stem has been killed by fire (Perry, 1991).

Impact of fire on sustainable forestry

Fire is a natural component of many ecosystems but it can adversely affect the ability of forests to produce sustainable levels of goods and services. Fire kills vegetation; even fire-tolerant trees that sustain injury from fire may be more susceptible to attack by insects or fungi (Amman and Ryan, 1991). More intense fires can kill all vegetation on a site and destroy years of growth in a matter of hours. Habitat for indigenous flora and fauna may be lost. Usually, many years are required for a site to recover from a forest fire. The destruction of vegetation by fire causes soil erosion, especially on steep slopes, which can lead to landslides and the siltation of water supplies.

Approximately 50 percent of the dry biomass of woody vegetation is composed of carbon (Brown and Lugo, 1982). When forests burn, a high proportion of the carbon is released into the atmosphere as carbon dioxide and other greenhouse gases. Increasing atmospheric levels of these gases cause concern because they may influence global climate (FAO, 1990a). After fossil fuel burning, forest vegetation burning is the second largest source of greenhouse gases and accounts for about 20 to 30 percent of the annual emissions of these gases at present (IPCC, 1990).

Intentional fires

Fire is used to clear large areas of forest for agriculture. Tropical deforestation and associated burning are occurring at record rates and are currently estimated to be 15.4 million ha per year (FAO, 1993). This represents a significant increase from the 11.3 million ha estimated a decade ago (FAO, 1982). Much of this clearing is done to support shifting cultivation (Seiller and Crutzen, 1980). Fire is an important silvicultural tool for slash disposal, fuel reduction and the preparation of sites for planting or natural regeneration (Vélez, 1991; Wade and Lundsford, 1990).

Wildfires

A wildfire is defined as "any fire occurring on wildland except a fire under prescription" (FAO, 1986). Long-term statistical data on the number, area and cause of wildfires are available for relatively few countries; however, recent estimates indicate that approximately 12 million to 13 million ha of forests and other wooded lands are burned annually by wildfire (FAO, 1992). Data for Europe and North America have been summarized by the United Nations Joint FAO/Economic Commission for Europe (ECE) since 1978 (FAO/ECE, 1986; 1990). For the period 1980-1988, these data indicate that an average of 585 000 ha was burnt annually in Western Europe, largely in the Mediterranean region, and 3 478 200 ha in North America. In Brazil, 201 263 ha of the country's 6 million ha of planted forests were burnt by wildfires during the period 1983-1988. The estimated cost of replacing these forests is $US154.3 million (Soares, 1991).

Occasionally, catastrophic wildfires occur. In 1982-1983, following a severe drought, some 3.6 million ha of primary and secondary rain forest were destroyed by the largest wildfire in recorded history in East Kamilantan, the Indonesian portion of the island of Borneo (Cougill, 1989). In 1983, the "Ash Wednesday" fire burned over 340 000 ha in southern Australia and resulted in 300 000 farm animals killed, 2 500 homes damaged, 3 500 people injured and 75 fatalities (Robertson, 1990; Rothsay, 1990).

Most wildfires are caused by humans. Careless use of fire during agricultural operations is a major cause of wildfire. In the Mediterranean region, many fires are caused by shepherds who ignite forests and grassland to promote a new flush of green grass for their herds. Farmers often use fire to eliminate crop residues or prepare land for planting. These fires frequently spread into surrounding forests. Urban populations often do not appreciate fire and its consequences. In the Mediterranean region, careless smokers or untended smouldering campfires cause about one-third of the fires in the region (Velez, 1990). In Honduras, a country with extensive forests, the main cause of wildfires is human activity, including: the restoration of rangelands, the extermination of insect pests and the preparation of fields for crops or disposal of agricultural residues (*Unasylva*, 1990).

The production of two non-wood products causes forest fires in some parts of India: tendu leaves, *Diospyros melanoxylon*, which are used for cigarette wrappers; and the mahua flower, *Madhuca indica*, which is used for a beverage. Fires are set to promote a better flush of growth of tendu leaves or to clear the forest floor for the collection of mahua flowers. Often untended, these fires spread to surrounding areas (Saigal, 1990).

Arson fires may be ignited for private vengeance, personal conflicts over ownership, hunting rights or government forest policies. Another motive for arson is to change land-use classification and permit home building in former forest areas (Vélez, 1990).

Natural factors, such as dry lightning storms, cause wildfire in remote, inaccessible regions of Australia, the Russian Federation and western North America.

Factors influencing fire occurrence and behaviour

Fire depends on fuels more than any other factor. Forest fuels are generally classified into three categories; ground fuels, surface fuels and aerial fuels. Ground fuels include duff, decayed wood and peat. Surface fuels consist of the loose litter on the forest floor and include fallen foliage, twigs, bark, cones and small branches. Aerial fuels include all burnable material, living or dead, located in the understorey or upper forest canopy.

Climatic factors such as temperature, moisture and atmospheric stability influence the probability of an ignition and the rate at which fuels are consumed by fire. Generally speaking, increasing temperatures, decreasing moisture levels and increasing wind velocities favour the intensity and rate of spread of fires. This is the case in the Mediterranean where inland summer winds can cause relative humidity to drop and spread fires by carrying sparks long distances (Vélez, 1990).

Topography can significantly influence fire behaviour. Steep slopes favour the spread of fire; a fire moving up a steep slope often resembles a fire spreading before a strong wind (Brown and Davis, 1973).

Forest fire management

Fire management encompasses three activities required to protect wildland resources from fire: prevention, presuppression and suppression. Fire management also includes the use of prescribed fire to meet land management objectives (FAO, 1986; USDA Forest Service, 1990).

Prevention. Prevention includes two general areas; activities directed at people, the major cause of fire, and activities directed at mitigating the flammability of the forest resource (Vélez, 1990). The former include public information campaigns and fire prevention messages. The latter include fuel management to reduce fire risk (e.g. prescribed burning, thinning, brush removal).

Legislation must complement fire prevention by establishing the setting of incendiary fires as a crime and penalizing offenders in proportion to the damage caused (Vélez, 1990). Prevention also benefits from regulations defining the conditions under which intentional burning can be undertaken.

Prescribed burning is an effective fuel management tool in forests of fire-tolerant species and benefits include reduced hazardous fuels, disposal of logging debris, site preparation for seeding and planting, improved wildlife habitat and management of competing vegetation (Vélez, 1991; Wade and Lundsford, 1990).

Presuppression. Presuppression includes all fire management activities planned and accomplished in advance of an ignition. They are designed to ensure effective suppression and include fire planning, detection, dispatching, fire danger rating, fire weather monitoring and suppression training and qualification (USDA Forest Service, 1990).

Suppression. The objective of fire suppression is to suppress wildfires at minimum cost consistent with land and resource management objectives (USDA, 1990).

There are three methods for bringing a wildfire under control. A *direct* attack is an attack on the burning edge of the fire and is used when fires are small. A *parallel* attack involves the construction of a fire line parallel but close to the edge of the fire. An *indirect* attack is used when the fire is too intense for other means of attack and entails the construction of fire lines some distance from the fire edge and the burning out of all intervening fuels (Chandler, *et al.*, 1983).

With an effective fire management programme in place, most fires can be successfully controlled during the initial attack. This often involves the deployment of a single fire brigade with appropriate equipment. In the United States, approximately 90 percent of forest fires are extinguished during the initial attack.

Large conflagrations require the deployment of a project fire team, sometimes composed of several hundred people. Effective use of these teams requires planning, coordination and an effective organization. In the United States, the Forest Service, the Bureau of Land Management and other public agencies have adopted the Incident Command System (ICS) as the organizational model for large project fires. ICS is intended to function in any emergency incident and operates on the basis of a series of subfunctions or units (e.g. operations, plans, logistics and finance) (Chandler, *et al.*, 1983).

Aircraft are used to support various fire management operations. Besides using small aircraft for fire detection, both fixed-wing aircraft and helicopters are used to deploy fire fighting crews. Air tankers support ground forces by dropping water or chemical retardants on portions of a wildfire that is burning with high intensity. This provides a cooling effect and allows ground crews access to the fire for either a parallel or indirect attack. Aircraft equipped with airborne thermal infrared scanners can map fire perimeters and identify "hot spots" which are then attacked by aerial tankers.

INSECTS AND DISEASE

Forests are also damaged by various pests. These include insects, mites, fungi, bacteria, parasitic plants, anthropogenic pollutants and other agents.

Insects

Insects surpass all other terrestrial animals in number (Borror and Delong, 1960). Approximately 751 000 insect species, or 54 percent of the world's known living organisms, have been described (Wheeler, 1990). Many perform essential functions in ecosystem survival. An example is the important activity of pollinators in the reproductive cycle of flowering plants or insects that are instrumental in the breakdown of dead organic material or that function as natural enemies of pests.

Other insects are vectors of plant, animal or human disease or feed on crops, livestock, stored products or trees. Under favourable conditions, they can reproduce rapidly and cause damage. Throughout much of human history, campaigns have been waged against these pests. For example, plagues of migratory locusts are mentioned in the Old Testament of the Bible and the Koran (FAO, 1967).

Forests are subject to insect outbreaks capable of causing severe resource damage. Examples include the spruce budworm, *Choristoneura fumiferana*, a defoliator of *Abies* sp. and *Picea* sp. forests in eastern Canada and the United States (Blais, 1985); various bark beetles (e.g. *Dentroctonus* sp. in conifer forests of the southeastern United States, Mexico and Central America, *Ips* sp. in North America, Europe and the Himalayas) (Thatcher *et al.*, 1981); and the processionary caterpillar, *Thaumetopoea pityocampa*, a defoliator of *Pinus* sp. in the Mediterranean region (Buxton, 1983).

Disease

Plant disease is defined as "any deviation in the normal functioning of a plant caused by a persistent agent". Disease can be caused by abiotic (non-living) and biotic (living) factors. Abiotic factors include air pollution, temperature extremes, drought, chemicals or mechanical damage. Biotic factors include fungi, bacteria, virus, insects, mites, nematodes or parasitic plants.

Disease can be recognized by symptoms and signs. A symptom is an expression of disease. Diseases often have unique symptoms which are helpful in identifying the pathogen: reduced growth, dieback, decay, yellowing or chlorosis of foliage or abnormal growth such as cankers or witches'-broom. A sign is the presence of the disease-causing agent, such as the fruiting stage of a fungus or the occurrence of a parasitic plant.

Fungi are a leading biotic cause of tree disease. They cause wood decay, rusts, cankers, foliar diseases, wilts and root rots. Some fungi benefit trees. Mycorrhizae act as extensions of a tree's root system and increase water and nutrient uptake and resistance to root disease (Manion, 1981). Several groups of parasitic plants cause growth loss, deformity and tree mortality. The leafy mistletoes (Family: Loranthaceae) infest both hardwoods and softwoods. Dwarf mistletoes, *Arceuthobium* sp. (Family: Viscaceae) are major pests of conifers (Hawksworth and Weins, 1972). Nematodes provoke diseases such as the wilt disease of pines caused by *Bursaphelenchus xylophilus*. Several pines indigenous to China and Japan are sensitive to this nematode and widespread tree mortality has resulted (Mamiya, 1976). Air pollution, resulting from increased urbanization and industrialization, together with increased demands for mobility and use of electricity, has become a major disease-causing agent in some forests (Smith, 1990).

Pest complexes

Often the combined action of insects, disease and associated environmental factors damages and ultimately kills trees. Some insects are vectors of plant disease and disperse the pathogen to suitable host material. Bark beetles inoculate their hosts with spores of blue stain fungi, *Ophiostoma* sp., which colonize the sapwood and disrupt the flow of water to the crown. This hastens the death of the tree and provides more suitable conditions for developing bark beetle broods (Drooz, 1985). Similarly, several species of bark beetles transmit Dutch elm disease, caused by the fungus *Ophiostoma* (= *Ceratocystis*) *ulmi* (Manion, 1981).

Root disease fungi often weaken their hosts but do not kill them. If infected trees are exposed to additional stress, such as insect defoliation or drought, they are further weakened and predisposed to attack by tree-killing insects. Trees affected by root disease are often foci for bark beetle attacks following drought.

Diebacks or declines are believed to be caused by the interaction of several factors, resulting in gradual tree deterioration. Symptoms include reduced growth, yellowing or chlorotic foliage, dieback of branches and roots and eventual tree mortality. Causal factors may include drought, off-site plantings, root disease, insects and air pollution (Manion, 1981). A regional decline affecting many tree species appeared in Europe during the late 1970s. The complex of stress factors responsible for this decline is not fully understood. However, many investigators believe the deposition of toxic, nutrient, acidifying and/or growth-altering substances of anthropogenic origin to be an inciting factor (Schutt and Cowling, 1985).

Impacts of insects and disease on sustainable forestry

Every part of a tree can be host material for insects and disease. Trees of all ages, from seedlings to mature trees, are subject to attack. In addition, insects and diseases are pests of logs and wood products.

Like fire, these agents have far-reaching ecological, social and economic impacts. Pest activity can significantly reduce yields of wood products. In the United States, bark beetles alone kill an average of 25.5 million m^3 of sawtimber and pulpwood annually (USDA Forest Service, 1958). Yields of fruit, mast or other food products on which wildlife, livestock or humans may depend, may also be significantly reduced. In India and many other countries, defoliating insects decrease the availability of hardwoods, a valuable source of fodder (Verma and Parry, 1991).

Introduced pests can eliminate a host plant from an ecosystem and reduce biological diversity. For example, chestnut blight, caused by the fungus *Endothia parasitica*, eliminated *Castanea dentata* as a major component of the hardwood forests in the eastern United States (Manion, 1981).

Extensive areas of forest damaged by defoliating or tree-killing insects are unsightly. Consequently, recreational and scenic values of forests are lost. Trees that are weakened or killed by insects and disease in developed forest recreation areas are a safety hazard to people using these areas. Dead trees left behind in the wake of pest outbreaks increase the volume of combustible fuels. Consequently, when an ignition occurs, resultant wildfires will burn more intensely and be more destructive and more difficult to extinguish.

In the United States, fungi causing decay in living trees account for more loss in sawtimber than fire, insects, weather or any other disease agent (USDA Forest Service, 1958). Decay of wood products is also significant. Approximately 10 percent of the timber harvested annually is utilized to replace wood that has deteriorated through decay fungi (Manion, 1981). Insects can also cause extensive damage to wood in use. Termites (Order: Isoptera) are major pests of living trees, homes and other wooden structures (Findlay, 1967).

Factors which influence pest abundance

As a rule, pests do not cause serious damage to forests unless they are sufficiently numerous. When designing pest management programmes, it is important that forest managers understand the mechanisms that influence pest abundance.

Quality of host material. As tree vigour declines, so does the tree's ability to resist attack. Examples include: reduced conifer resistance to bark beetle attacks because of drought, flooding, root disease, etc. (Rudinsky, 1962); and the decline of *Pinus echinata* in the southeastern United States, believed to be caused by a soil-borne fungus, *Phytophthora cinnamomi*. Trees growing on low-nitrogen soils with poor internal soil drainage are most severely affected by this disease (Mistretta, 1984).

Quantity of host material. Agricultural fields containing a single crop are especially favourable for the development of pest populations because they provide a large volume of host material. Tropical forests, on the other hand, where hundreds of plant species occupy a single hectare, rarely succumb to large-scale outbreaks (Speight and Wainhouse, 1989).

Natural forests of one or two species, relatively common in the boreal and temperate forests of the Northern Hemisphere, are often subject to pest activity. Examples are the outbreaks of mountain pine beetle, *Dentroctonus ponderosae*, in pure *Pinus contorta* forests of western North America (Amman *et al.*, 1977).

Forest plantations, which often consist of a single species, are particularly subject to pest damage. In Viet Nam, extensive planting of hillsides with *Pinus merkusii* and other pines has led to frequent outbreaks of pine caterpillar, *Dendrolimus punctatus* (Billings, 1991).

Natural enemies. Parasites, predators, disease and competing or antagonizing agents regulate pest numbers. Examples include parasitoids of the orders Hymenoptera and Diptera (Girling, 1990); nematodes such as *Deladenus siricidicola* (Bedding and Akhurst, 1974); predators such as birds, spiders and a wide range of other insects; pathogens, including bacteria (e.g. *Bacillus thuringiensis* var. *kurstaki*), fungi (e.g. *Beauvaria bassiana*) and baculoviruses, which attack certain insects in the Hymenoptera and Lepidoptera orders (Girling, 1990).

Climatic factors. Climate can also influence pest abundance. Climatic factors such as low annual precipitation, low mean maximum temperatures in January and low mean minimum temperatures in July are associated with frequent outbreaks of western spruce budworm, *Choristoneura occidentalis* (Kemp, 1985). Timing of rainfall is known to influence fungal activity. When the needle fungus, *Dothistroma pini*, was introduced into Kenya, a region of summer rainfall, *Pinus radiata* was so severely damaged that the species had to be dropped from the planting programme (Odera and Arap Sang, 1980). Climatic events such as storms cause mechanical injury and predispose trees to pest attack. During the late 1960s and early 1970s, storms caused windthrow over portions of Norway and Sweden. Windthrown *Picea abies* were invaded by the bark beetle, *Ips typographus*. Severe droughts during the period 1974-1976 reduced the vigour of standing trees and predisposed them to attacks from subsequent generations of bark beetles (Speight and Wainhouse, 1989).

Human activities. Atmospheric pollution, logging, road construction, the establishment of single species plantations and even fire prevention can create favourable conditions for increased pest activity.

The accidental introduction of insects and pathogens has caused catastrophic losses, primarily through international transport of animal and plant materials into new habitats. Often these agents are of minor consequence in their native habitat. However, introduced into a new environment and exposed to sensitive hosts in the absence of natural enemies, they can become pests. Examples include fungi such as the Dutch elm disease fungus, *Ophiostoma ulmi*, and insects such as the cypress aphid, *Cinara cupressi* and the oriental scale, *Aonidiella orientalis*. Forestry practices have caused accidental pest introductions. White pine blister rust, *Cronartium ribicola*, was introduced into North America on *Pinus strobus* planting stock (Manion, 1981). A pine woolly aphid, *Pineus pini*, was introduced into Kenya and Zimbabwe on *Pinus taeda* scions, sent from Australia as part of an international tree improvement programme (Barnes, Jarvis and Schweppenhauser, 1976). Atmospheric pollution has become a major cause of disease in some forests, especially in industrial countries. Heavy metals, acid rain, sulphur dioxide and ozone have been implicated as disease agents near industrial centres and, more recently, over more remote forest areas (Schutt and Cowling, 1985; Smith, 1990). Jacobson and Hill (1970) identified and described symptoms associated with gaseous pollutants.

Protecting forests from pests

Integrated pest management (IPM) is the best way to protect forests from insects and disease. IPM involves both decision-making and action elements. The emphasis is on pest monitoring, understanding the underlying causes of outbreaks and maintaining or improving the health of forests, rather than on controlling pests (USDA Forest Service, 1988). An integral part of IPM is to ensure early detection of pests, delineate outbreak boundaries and predict future population trends and damage. IPM emphasizes pest prevention and makes use of one or more tactics (e.g. silvicultural, biological, genetic, chemical) to reduce pest-caused losses to a level where resource management objectives can be met now and in the future. It is a dynamic process and new approaches and new technologies are continuously tested and evaluated. Those that prove effective are quickly integrated into ongoing programmes.

IPM is still evolving as an integral part of sustainable forest management (USDA Forest Service, 1988). In many cases IPM has not been adopted, and few true IPM systems exist in forestry today. Reasons include a lack of knowledge about certain pests or pest complexes and their host interactions, a lack of proven pest management tactics, a shortage of funds, insufficient data on pest-caused losses and a lack of interest on the part of forest managers who must integrate preventive strategies into operational programmes. Too often, forest managers disregard pest damage. Consequently, outbreaks are treated as a crisis and action is usually taken too late to prevent resource damage. A key challenge for forest resource managers is to integrate pest potential and management into strategic forest plans.

CLIMATE CHANGE AND FOREST PROTECTION

The earth's climate has changed throughout geological history. These changes have influenced the existence, abundance and distribution of plants and animals. Today, there is much concern that human activity, such as the burning of fossil fuels and tropical deforestation, may be changing global climate at an unprecedented rate and that this could profoundly affect forests and their sustainability.

The greenhouse effect

Greenhouse gases regulate the earth's temperature. The most important are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and chlorofluorocarbons (CFCs). Theses gases trap heat which would otherwise escape the earth's atmosphere. Without them, the mean surface temperature of the earth would be about -30°C instead of +15°C, and life as we know it could not exist (FAO, 1990b).

Global climate change

An increase in atmospheric CO_2 or other greenhouse gases could result in a warming of the atmosphere and changes in global climate. There is now strong, although not yet conclusive, evidence that this is happening (FAO, 1990b). Increases in atmospheric CO_2 and CH_4 have been measured since about 1850. This increase has been accompanied by a 0.5°C rise in temperature, brought about by a number of natural and anthropogenic (human) causes. Leading anthropogenic factors include the burning of fossil fuels and biomass burning associated with deforestation and land-use changes (IPCC, 1990).

If present trends continue, it is predicted that the atmospheric concentration of CO_2 will double from the pre-industrial revolution level of around 260 ppm by the year 2065 (Pollard, 1985). This will probably influence global and regional climates. A temperature increase of 2 to 5°C is predicted. Temperature is expected to increase more with latitude and will therefore exert a major effect on northern ecosystems. Precipitation is also expected to increase generally because of the increased energy available for evaporation (Harrington *et al*, 1991).

Potential effects of climate change on forests

Global climate change can affect forests both positively and negatively. These effects could be far-reaching and affect all of the world's forests. One possible effect of global climate change is a shift in the natural ranges of tree species and forest types towards polar latitudes. Since climate change may be more pronounced in upper latitudes, temperate and boreal forest regions are expected to be more strongly affected. A shift in the range of a species could result in its occupying a greater land area. On the other hand, it could force a species to occupy areas of less productive soils, resulting in reduced growth and increased susceptibil-ity to pests. This has been predicted for *Pinus taeda*, a species indigenous to the southern United States, if its natural range were to shift northwards into the poorer soils of the Appalachian Mountains.

Higher temperatures and increased precipitation could result in increased tree growth. In addition, many plants, including trees, are known to produce more biomass when CO_2 levels are elevated. Transpiration rates of many green plants are also reduced in atmospheres with an elevated level of CO_2. Consequently, forests may also be more tolerant of moisture stress.

Increased temperatures, on the other hand, can place trees under stress and increase their susceptibility to insects and disease. It has been suggested that a widespread decline of *Betula* sp. in eastern Canada during the late 1950s and 1960s was related to a warming trend (Hepting, 1963). If this is so, forest decline could become more frequent in the future, especially where there are high concentrations of anthropogenic pollutants in the atmosphere.

While some global climate models (GCMs) predict an overall increase in precipitation, some also predict that continental regions will have reduced precipitation/evaporation ratios, with doubled CO_2. This would be accompanied by reduced soil moisture, especially during the summer growing season (FAO, 1990b). Reduced moisture levels in continental forest ecosystems could mean a higher incidence of wildfire which, in turn, would result in more CO_2 released into the atmosphere. As stated earlier, drought is a key factor that places trees and forests under stress and increases their susceptibility to invasion by insects and disease. If more trees are killed by these agents, the volume of combustible fuels will increase. Consequently, when wildfires occur, they will burn more intensely, cause more damage and be more difficult to extinguish (Sedjo, 1991).

Forests as agents for mitigating effects of climate change

Green plants are a principal component of the global carbon cycle. Through photosynthesis, they remove CO_2 from the atmosphere. Trees accumulate and store carbon as woody tissue. Consequently, forests are carbon sinks. Brown and Lugo (1982) estimate that tropical forest ecosystems can store from 46 to 183 tonnes C/ha. These forests contain approximately 46 percent of the world's living terrestrial carbon and 11 percent of the world's soil carbon. Plantations of short rotation with fast-growing trees have the potential to store from 8 to 78 tonnes C/ha, depending on the species, site and length of rotation (Schroeder, 1991). Mature or overmature forests, which are no longer adding increment, have also reached zero carbon accumulation. When trees die, burn or are harvested, a portion of the carbon is once again released into the atmosphere.

Because of their ability to store carbon, forests can potentially mitigate the effects of global climate change. Reduction in forest burning and clearing and increased tree planting have been recommended as forest sector responses to the climate change issue (FAO, 1990a). Accelerated tree-planting initiatives are already under way in several countries. In 1991, representatives of 67 countries and international agencies participated in the development of the Noordwijk Declaration on Climate Change. One provision of this declaration was to increase the net forest area by 12 million ha per year by the beginning of the next century (Anon., 1989).

Initiatives to increase net forest area should produce benefits independent of climate change concerns as defined in land-use plans and forest management strategies (FAO, 1990b). If tree planting increases significantly in the future, increased protection will be necessary to ensure the trees' survival.

SUMMARY AND CONCLUSIONS

Fire, insects and disease are key factors affecting the sustainability of the world's forests. While these agents may have important functions in forest ecosystems, they can also affect the ecological, social and economic benefits which forests provide. The effects of fire, insects and disease can range from a slow drain on forest growth to extensive tree killing over large areas. Logs and wood products are also subject to damage by insects and decay fungi.

Fire and pest management programmes are designed to reduce losses in line with resource management objectives. They include both prevention and suppression strategies. Detection and monitoring are important in ensuring that fire and pest activity is discovered before extensive damage occurs and in providing data to support decisions on appropriate tactics. For maximum effectiveness, forest protection should be an integral part of sustainable forest management and should appear as a key element of strategic forest plans.

The probable change in global climate through increasing levels of CO_2 and other greenhouse gases could have both positive and negative effects on forests. One potential effect is increased forest susceptibility to fire, insects and disease. Furthermore, initiatives to increase forests' ability to function as carbon sinks will require accelerated protection efforts.

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Part 2

Creating a supportive environment for sustainable forest management

Policy, legal and institutional aspects of sustainable forest management

M.R. de Montalembert and F. Schmithüsen

This paper discusses major policy, legal and institutional aspects of forest management. The dynamic nature of development requires continuous adaptation in policies, institutions and regulations aimed at maintaining an effective incentive framework for sustainable forest management. Such a framework should combine a certain flexibility with the stability and security necessary for long-term continuity in forest management. The paper includes sections on laws and regulations for sustainable forest management – nominal and functional forest law, forest tenure, etc., and institutional and organizational aspects; the changing role of the public sector and expanding roles of the private sector and non-governmental organizations; and information, communication and training – facilitating the diffusion of knowledge, reinforcing the social base of sustainability through understanding and dialogue and gradually strengthening technical skills and capabilities. The paper concludes that the most important factor is changing attitudes and capacities from the traditional emphasis and focusing on the more comprehensive and partnership approaches required in sustainable forest management.

INTRODUCTION

Recent analyses show that the performance of forest management programmes depends importantly on their institutional context, including prevailing policy orientations. The dynamic changes of forest management affect institutional effectiveness: demographic growth and population movements increase pressures on forests, and more land is cleared for agriculture to meet

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basic food needs. Tensions exist between resource stability and the day-to-day subsistence needs of growing local populations.

Forest management must address increasingly complex demands from a growing number of users: the state wishes to mobilize the economic potential of a renewable resource to generate revenues and employment; private entrepreneurs work to increase their profit and competitiveness; local people rely on the forest for food, fodder, fuel and income and it may also constitute their cultural basis; the public expects the forest to be a major component of a stable and amenable local environment; recent concerns stress the global role of forests in relation to climate change and biodiversity conservation. Inequitable development patterns exacerbate pressures on forests further; more rural poor and landless are forced to migrate into less productive and more ecologically fragile areas. These forests are destroyed for unsustainable farming instead of being managed properly for alleviating poverty and environmental protection.

Sustainability in forest resources management is based on balancing private and public interests and the uses and benefits of present and future generations. It also requires the following: more global understanding of the potential current and future value of forest ecosystems and the full range of benefits, both private and public; reinvestment and/or new investment in the forest resource; and, at least sometimes, a restriction on present utilization by curtailing exploitative short-term forest uses.

This paper discusses major policy, legal and institutional aspects of forest management under the following basic assumptions. First, our underlying concern is development, i.e. securing improved livelihoods for present generations while maintaining the forest heritage and its potential for the benefit of future generations. Second, we consider this stable forest potential within the broader context of rural development, recognizing that the dynamics of land use must allow for changes while maintaining the balance between forests and other land uses where trees also have a role. Third, we believe forest stability and sustainable forest management can only be achieved by clearly identifying management responsibilities and reconciling the diverse and possibly competing interests through dialogue and partnership-building. Fourth, the shift in emphasis on the environmental protection function is fully recognized but it does not diminish the economic importance of the forests' production function or the need for forestry activities to compete effectively for scarce investment resources and to be valuable enough for users to commit themselves to sustainable management.

Our approach builds on the principle adopted by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro as part of the non-legally binding authoritative statement on forests that: "national policies and strategies should provide a framework for increased efforts, including the development and strengthening of institutions for the conservation, management and development of forests". The dynamic nature of development requires long-term flexibility and adaptation in policies, institutions and regulations aimed at maintaining an effective *incentive framework* for sustainable forest management.

THE NEED FOR A SOUND POLICY FRAMEWORK

For sustainable forest management, it is essential that an overall priority of national policy is development sustainability across all sectors and security of sustainable livelihoods for present and future generations. Without a clear focus on development patterns which balance human activities with nature's ability to renew itself, sustainability remains a theoretical concept subject to diverse interpretations. Each country decides how best to translate this policy orientation into criteria for monitoring and evaluating sustainability development. The main development policy stream can thus encourage consistent sustainability approaches among all sectors. This is particularly important for those activities dealing with renewable natural resources and competing for the land resource. Such a context constitutes a prerequisite to, and a basic incentive for, sustainable forest management.

Within this broad context of rural development and land-use and environmental policy, forest policies deal more specifically with forest resources and their management: the socio-economic aspects of increasing sectoral performance; the role of forest and tree resources in land use and rural development; their function in nature conservation and environmental protection.

Most existing forest policies were conceived to address simpler situations. Smaller populations and less competition among land users reduced pressure to focus on the stability of forest ecosystems and their sustainable management. A ministerial declaration would express concern for maintaining forest areas but would not prevent these areas from being considered able to regenerate themselves naturally while constituting a land bank for further agricultural expansion. The declared intention was to protect a seldom well-demarcated estate, sometimes confiscated from local groups who had owned it from time immemorial. Forest policies focused principally on timber production and its sustained yield and restricted other activities. Such a negative posture generated conflict among interested parties (forestry agencies, the private sector, local groups). Furthermore, fiscal and pricing policies as well as contractual policies focused mostly on harvesting and not on management. Hence, former forest policies were weak because they lacked focus on comprehensiveness and sustainable management of the forest ecosystem and on generating cooperation among major actors, rural communities, private entrepreneurs and the forestry institution itself.

Today, forests must be managed in a much more interdependent and complex context. The most critical change required is to establish a partnership process. Consequently, forest policies should involve major interest groups in forest management decisions through consultations. In particular, consultations must enable people affected by the emerging management arrangements to articulate their interests. The political system should decide how to reconcile or even combine divergent interests and how to share costs and benefits among the main actors and beneficiaries. However, consultations legitimize the involvement of all major actors and solicit their commitment to a more comprehensive approach to sustainable forest management.

In modifying the policy framework to provide effective incentives for sustainable management, the following considerations are particularly important:

- *Land-use planning and policies:* recognizing forests as a major renewable natural resource of value for present and future generations.
- *Macroeconomic policies and structural adjustment measures:* identifying and assessing possible negative impacts of agricultural programmes or privatization policies on forest conservation – cash crop expansion, or rural people migrating to expand subsistence farming, etc.
- *Policy interactions* between forestry and related sectors such as agriculture, livestock, infrastructure, industry, energy, mining: verifying and developing consistency and complementarities with forest management activities; and minimizing the negative impacts of specific pricing and incentive

measures in other sectors against sustainable forest management and use.

- *Conservation and wise utilization of forests*, its unequivocal recognition as a national priority in forest policy and its simultaneous reflection in environmental and development policies. Sustainability is a long-term perspective characterizing the application of such a policy to a demarcated permanent forest estate comprising production forests and protection forests.
- Forest policy should focus on the *behaviour of various social groups* with interest in using the forest resources and encourage them to organize themselves. Sustainability is likely to result from convergent and comprehensive approaches that reconcile local community needs with the broader demands for economic growth and environmental stability. Different user groups should be recognized. Timber and other raw materials are sold to the market or to industry by private entrepreneurs, some other products such as fodder or wild foods are used as a common resource by local groups while others, such as water flows or biodiversity, interest the broader community. Within such varied interests, the policy should encourage flexible approaches that ensure sustainability across a variety of tenure, use and management regimes in different ecological and socio-economic contexts.
- *Forest dwellers and neighbouring communities:* their rights of access to those products on which their livelihood depends should be recognized. Forest policy must recognize *their secure and sustainable livelihoods* and the protection of the cultural integrity of their forest heritage. The policy must therefore encourage the design and implementation of management approaches enabling local people to organize themselves and be involved as preferential partners and beneficiaries.
- *Fiscal policies:* revenues accruing to the government cannot be based solely on forestry taxes and fees in isolation from revenues generated by the general taxation system. Fiscal policies, general and forestry-related, influence the willingness and ability of the institution in charge of forest management to invest in its sustainability. Many countries with large privately owned forest resources have a favourable taxation regime for forest revenues in order

to make continued investment in forest management attractive and competitive against other options. Financial grants and compensations may also be considered: grants for improving long-term production potential such as reforestation and forestation, silvicultural improvements and infrastructure; compensation for costs of specified management measures undertaken by forest owners in the public interest, such as improving the stability of special protection forests, construction measures for land or managing intensively-used recreation forests; compensation for defined losses or foregone benefits of forest owners as a result of voluntary harvesting restrictions in certain areas.

- *Pricing policies* for all marketed forest goods and services are particularly important in determining the economics of forest management and especially the levels of investment and reinvestment for conserving and improving forest resources. The interplay of market forces and competition should make forest product prices reflect real economic values while monitoring the possible interactions of price differentials with alternative non-forestry productions. This is not a simple issue, but efficient economic performance is important in sustainability. The markets for forest products should operate so that a fair share of revenues accrues to those who are actually responsible for managing the forest: a government entity, a private concessionaire, a forest owner or a local community or user group.

The most important issue regards on-going analyses of the impact of the various elements and identifying the need for change so that long-term management is encouraged. This requires regular consultations among interested parties to identify issues and possible constraints of current policies as well as potential solutions through reforms or adaptation in policy.

LAWS AND REGULATIONS FOR SUSTAINABLE FOREST MANAGEMENT

Present legislation on conserving and developing forest resources does not sufficiently reflect the principle of sustainability. Indeed, many laws and regulations are inconsistent and often contradictory to long-term forest management.

More emphasis on sustainable forest resource development in national policies must lead to legislation being systematically reviewed and often considerably modified.

Such an adjustment should reinforce existing provisions that aim at implementing sustainability and incorporate new regulations which consider the interests of future generations, eliminating those provisions that are incompatible with sustainable forest utilization and development. This implies considerable efforts in further improving and elaborating nominal as well as functional forest law.

Nominal forest law

Nominal forest law comprises legislation which specifically addresses forests and forestry. It refers primarily to forest law itself, dealing with forest conservation and development. It also includes complementary regulations and rules.

Like forest policy, nominal forest law has three important aspects: it is sector-specific legislation focusing on forest conservation and development and, as such, is part of the economic development and natural resources legislation; it is an important and integral part of land-use and rural development legislation concerning forests as part of rural space; and it is an indispensable element of environmental protection law and of nature and landscape conservation legislation.

Present forest legislation is largely regulatory. The policy-makers who have shaped these laws, have largely focused on immediate benefits from timber production as the major or exclusive output from the recourse. They assumed that it would be sufficient to regulate forest cover maintenance and to prevent destructive practices. Regulatory measures will certainly remain important in standard forest laws but it is fairly evident that a comprehensive policy of sustainable forest management cannot be based on such measures alone.

Forest legislation has to provide a more consistent framework for participatory forest policies for people relying directly on forests. It particularly needs to offer incentives and/or compensation to private and communal owners who provide public benefits by managing their forests in a multifunctional manner and in accordance with the principle of sustainability.

Functional forest law

Functional forest law refers to a wide range of laws and regulations which address other subjects and problem areas. However, their provisions have some relevance or impact on forest conservation and development.

Legislation of particular importance to sustainable forest development may be grouped as follows:

- *Legislation referring to the general and specific aspects of environmental protection:* national environmental protection codes, air pollution control, etc.
- *Legislation principally concerned with renewable natural resources:* legislation related to agriculture, grazing, fishery, agrarian reform, erosion control, land rehabilitation and their various interfaces with forestry and combined production systems.
- *Legislation dealing with social and economic measures for developing rural space:* land tenure legislation, land-use planning legislation, tax legislation, etc.
- *Legislation concerning nature protection:* principally laws protecting flora, fauna and undisturbed landscapes; and hunting, wildlife and national parks legislation.

Forests and forest land use as well as the management of timber stands thus become subject to a varied network of legal provisions. This leads to an increasing interdependence between forest laws, on the one hand, and economic development laws as well as natural resources and environmental legislation, on the other hand.

The growing complexity requires a thorough analysis of the compatibility of the various laws and regulations. The following aspects need particular attention:

- the implications of expanding environmental and nature protection legislation on the evolution of forest legislation;
- the degree to which the respective provisions mutually support, contradict or even neutralize and obstruct each other;
- the scope in environmental protection laws for inserting or reinforcing specific provisions for forest conservation and management;
- the impact on sustainable forest management from evolving and improving natural resources and rural development legislation;
- the need to modify forest management regulations in order to be compatible and to support such legislation.

Forest management issues

Depending on social needs and the prevailing forest ecosystems, the *general objectives of the law* may cover a wide range of individual targets and goals. Points of general importance concerning a comprehensive sustainable forest utilization approach are:

- protecting the forest cover and its regional distribution in order to maintain a stable environment and to provide a basis for economic and social forest development;

- protecting all prevailing natural forest ecosystems in order to maintain biodiversity and landscapes;
- establishing and supporting a viable and multifunctional forest economy, combining ecological conservation and economic resource utilization;
- establishing new forests as far as they are required for environmental reasons and/or economic development.

If at all, forest laws refer to sustainable forest management usually for wood production only. Sustainable forest management, however, must also address the conservation and management of forest ecosystems as a whole.

Thus, the law has to define sustainability both in terms of the diversity and stability of the various forest ecosystems and of their contribution to present and future development needs. It has then to determine the meaning and relevance of sustainable management with regard to present and potential outputs, in particular:

- the production of fuelwood and construction timber for local consumption as an input for rural economics;
- the production of various categories of industrial wood as a basis for an industrial sector economy;
- the supply of a wide range of non-wood products both for local and industrial uses;
- the provision of protective services against the consequences of natural calamities such as avalanches, erosion, landslides and floods;
- the maintenance of the protective role of the forest cover for groundwater resources;
- the provision of recreational uses for urban areas and/or tourist development.

Prevailing forest practice regulations need to be systematically reviewed. Such a review should aim at ascertaining whether the existing provisions related to timber harvesting, road construction, reforestation, silvicultural improvements and management planning are consistent with sustainable resources development. Furthermore, the requirements of biodiversity protection and landscape conservation should be integrated into forest utilization practices. Biodiversity and landscape conservation are in fact an essential frame condition for sustainable forest development.

Laws and regulations usually contain little on *public participation in management decisions*. Hitherto, forest management planning has been mainly considered a technical issue and left to forest owners and forest services. Revised legislation is necessary in order to:

- provide institutionalized processes for forest owners, user groups and political entities to determine the range of forestry outputs, the management objectives and the necessary measures to reach such objectives;
- generate the political commitment essential for implementing sustainable resource development and to provide the necessary financial basis based on equitable cost sharing between forest owners and public entities.

Incentives are important to support sustainable forest management objectives involving immediate interests of forest owners and entitled user groups as well as the public and the usually more long-term interests of the community. Legislation should provide incentives that promote practices and benefits that concern the community as a whole.

More appropriate legislation on sustainable forest uses needs to be implemented. Laws and regulations have actually been revised or are currently being reviewed; however, up to now it is doubtful whether legislative improvements have redressed forest destruction and wasteful utilization very much. Although primarily a political issue, legislation can provide an institutionalized basis for monitoring sustainable resource policies by:

- establishing the principle and the necessary mechanisms for regularly monitoring the state of forest resources nationally and regionally;
- checking the results of forest management planning, particularly concerning forest area, biodiversity and health of forest stands, outputs of public interest, etc.;
- evaluating the efficiency of public policies and related legal provisions with regard to the comprehensive objectives of sustainable forest development and conservation;
- providing the relevant information from monitoring and evaluation to government and parliament.

Forest tenure issues

The term, forest tenure, comprises both forest usage rights and various forms of forest ownership. Forest laws and regulations must include provisions covering the *different categories of tenure* and must determine:

- the categories and nature of usage rights and the extent to which they may be practised sustainably;
- the categories and nature of forest

ownership and the applicable management planning procedures;

- the rights and obligations of different categories of forest owners, particularly concerning land registration and demarcation;
- the conditions modifying the status of forest land, irrespective of ownership changes.

Many forest laws acknowledge *usage rights* as a matter of principle but they lack adequate provisions to protect forest usage rights and to allow their sustainable practice in determined forest areas. Management regulations, in fact, tend to disregard user rights and to provoke their abolition. This frustrates the local population, which may practise many forest uses and sustainable management patterns. In response, local people are compelled de facto to give up previous careful and long-term resource utilization and move to short-term and exploitative uses. New legislation should combine the principle of sustainability with a firm legal commitment to maintain and develop local uses and to provide the necessary legal protection for their practice.

Acknowledged and institutionalized community access to using forest resources is often important in determining local interest in maintaining the forest cover. The various forms of *community forest tenure* and *common property* are particularly interesting. Legislation should regulate:

- the rights and responsibilities of communal forest owners regarding sustainable uses and management practices;
- the possibility of consolidating forest usage rights by introducing new forms of ownership by the community or by groups of users;
- the possibility of transferring public forest land into community ownership either by land title registration, by long-term land-use agreements or by land leases.

Several countries do not yet have appropriate legal arrangements for *private forest tenure*. The law, geared exclusively to public ownership, may actually hinder private initiatives in tree planting. Such legislation should be reviewed with the objectives of:

- abolishing unnecessary forest regulations that prevent private landowners from planting part of their land with trees;
- introducing provisions that facilitate tree utilization together with agricultural crops and that promote efficient agroforestry practices;
- providing land-use agreements and land leases that allow private forestry on public land;
- providing a positive approach in

encouraging sustainable private forest management.

State forest tenure has two aspects. In some countries, it is one of various tenurial arrangements. The state forest service manages state forest land, usually in co-operation with communal and private forest owners. Under legal provisions, management standards are comparable to or higher than for other ownership groups, owing to the keen public interest in sustainable resource use. In other countries, state forest tenure is the dominant or exclusive category of forest ownership but the government allocates timber harvesting and forest management rights to private industry, for example as cutting permits, forest concessions, timber harvesting agreements, forest management contracts and land leases. Sustainable management practices should be reviewed in this type of tenure.

On the whole, *forest concession systems* are gradually moving from a largely exploitative stage to more long-term forest management contracts. Changes in legislation have to focus principally on provisions that:

- rationalize concession tenure by linking the size of granted forest areas and the length of the arrangement more specifically to the type of private operator, the level of raw material processing, the volume of industrial investment, and to the socio-economic contribution of the industry;
- reinforce the long-term management aspects by determining annual timber harvesting volumes instead of relying on area alone, by introducing sustainable wood production regimes and by providing incentives for improved utilization standards;
- foster reinvestment in maintaining the productivity of forest resources, for instance through the planting of logged areas, silvicultural improvement cutting, forest fire control and the improvement of forest infrastructure;
- contribute to a more systematic integration of requirements to maintain biodiversity and ensure landscape protection with forest concession regulations;
- encourage improved sustainable resource utilization, in particular by renegotiation at regular intervals (e.g. every five years) with an extension option if the performance has been satisfying and the proposals for improved management are mutually agreeable.

INSTITUTIONAL AND ORGANIZATIONAL ASPECTS

Institutional arrangements constitute the instruments for implementing national forest policies through forestry laws and regulations. Institutional capacities have generally been grossly underestimated. Institutional weaknesses constitute a major cause of unsustainable forest management and utilization.

Forest management in developing countries, particularly in the tropics, has been until now mostly the responsibility of government forestry institutions. These institutions have suffered significant and enduring problems: lack of proportionate resources to match the size of the public forest estate; inertia in adapting to new policies and development context; unwillingness to transfer forest management responsibilities to others; and a lack of experience with innovative approaches and methods, especially dealing with the socio-economic aspects of forest management under high demographic pressures. Finally, institutional capacity to manage public forests has been hampered by a lack of equipment, low salaries, excessive bureaucracy and a lack of rewards for professional capacities, poor training, uncertain career prospects, corruption, etc.

The evolving institutional context

The changing role of the public sector and expanding roles of the private sector and of non-governmental organizations (NGOs) mark a general policy trend in the evolving institutional framework of development. This is partly due to economic liberalization and the effectiveness of the market's regulatory influences.

However, changes in the institutional framework of forest management are not to be taken lightly. In many developing countries, the predominance of the state as forest owner reflects earlier low population densities in and around many forest areas and a genuine concern for their conservation. Now, genuine forest dweller communities have a role in forest management, reflecting their dependence on and responsibility for the resource. The shift in emphasis of forest concessions from harvesting to management is critical and has policy and institutional implications.

In a number of other countries, forests were removed from the control and management of local communities to ensure their protection from over-exploitation. In the devolution of management responsibilities, genuine old-settlement communities, with traditional rights and knowledge, should be distinguished from new settlements of rural poor, migrating from necessity, and encroachers migrating out of speculation. Any major change in the respective roles of the forestry institution, of the private sector and of local communities must consider the distinct needs and behaviour of these categories. The possible impacts on sustainable forest management need careful assessment, i.e. economic performance, social equity and ecological stability.

Under what conditions can a change in the respective roles of the main actors enhance sustainable forest management? What should be the nature of this change: the devolution of land and forest management to the private sector, the transfer of usufruct rights on the supply of goods and services from the forest, the recognition of communal control over a previous common property resource?

Public institutions

There is no country in the world where public institutions do not play a major role in forest management. Public institutions would seem to be better equipped for the following important aspects:

- Improving the knowledge of the resource and its value and potential through inventories of forests and other woody resources; monitoring changes in relation to other land uses and participating in comprehensive land-use planning and management.
- Analysing market and non-market incentives and their impacts on resource protection and resource utilization; monitoring reactions and behaviour patterns among the wide spectrum of land and tree owners and users (public, private, common) and other interest groups; identifying divergences of interest among concerned groups and facilitating dialogue and conflict resolution.
- Providing objective and up-to-date analyses and understanding of the sector's perspectives concerning supply and demand of goods and services and of potential market developments to orientate forest management and related investments; identifying the implications of current demands on the forest potential to meet those of future generations.
- Managing the state forest estate, accumulating experience and providing examples of "good" forest management.
- Encouraging and checking the implementation of forest management and harvesting regulations by private owners and concession operators; determining performance control standards based on the regular monitoring of physical land-use and forest management criteria; evaluating the relevant information submitted by the operator.
- Providing support to developing sustainable tree-growing and

management activities by rural people, the private sector and other organizations through information, extension and technical support.

- Encouraging an overall consistency of forest management approaches while deconcentrating initiatives and support at field level for building up partnerships with local forest managers and users and for establishing an effective dialogue.
- Cooperating with public institutions in other sectors on infrastructure development, population, energy, etc., and on coordinated approaches to intersectoral issues.
- Managing or assisting in the management of appropriate funding mechanisms in order to provide credit and stimulate investment in forest management as well as to compensate the costs to the private owner or the user group of restrictions imposed on the productive function as a means of safeguarding broader benefits of the forest both inside and outside its borders.

The increasing complexity of sustainable forest management places a major responsibility on public forestry institutions, and no other institutions can replace them. Their efficiency depends on the skills and attitudes of their staff, on modern administrative machinery and on the adequacy of their infrastructure and resources.

The private sector

Private sector organizations are essential partners in sustainable forest management. The entrepreneurship and management experience of private owners and enterprises can substantially enhance the performance and economic base of sustainable forest management. They represent by far the largest potential investor. The institutional framework should encourage the private sector to make long-term investments in sustainable forest management under conditions of profitability, fair competition and security which can compete with investment alternatives. Dialogue is essential and will be all the more effective if representative organizations can express the views of forest owners, including the smaller ones. Such organizations are essential channels for two-way communication with public institutions and for negotiations when needed. If properly supported and motivated, these organizations can strengthen the technical and managerial capacities of their members for sustainable forest management. Government institutions should also be efficient in checking and monitoring the effectiveness of sustainable management regulations. This is particularly important in those countries where major responsibilities in forest management are to be transferred to the private sector.

In a number of countries, structural adjustment programmes and a stronger orientation of macroeconomic policies towards the market are increasing the private sector's role in forestry. In many former centrally planned economies, the transition to a market economy implies the surge of the private sector as a new actor in forestry. Thus, the general trend is an increasingly important private sector as a partner in forest management. However, in most countries, concern for the long-term sustainability of forest resources and their public services underlie the reluctance to privatize public forest land. Forestry operations on public lands, such as harvesting, forestation and reforestation, are privatized under contractual arrangements which determine how the resources are managed and safeguarded and how revenues are distributed. This raises two important issues concerning forest management.

Special attention is needed with goods and services that are not traded or that are related to public services such as conservation and protection and whose values are difficult to assess. Examples include biodiversity, wildlife habitat, microclimate and water supply. The issue relates to reconciling private profit with the provision of public goods or intangible values in management systems that sustain the multiple roles and functions of forests. Hence, it is necessary to assess and monitor carefully institutional arrangements under which private enterprises are to operate in managing and utilizing public forests. In privately owned forests, the issue concerns the existence of adequate incentives for the sustainable and comprehensive management of the resource and the adequacy of the owners' technical and managerial capacities.

The other important issue concerns the contrast between private forestry and the new dimension of people's participation and the social benefits of forest management. The impact of private business development on local people must be assessed very carefully, particularly regarding vulnerable groups. Privatization of traditionally managed common lands may profoundly affect the access of local groups to the supply of important goods such as food, fodder or fuel. These groups should not be marginalized but should actually benefit from such development.

Non-governmental organizations

The diversity of NGOs and their expanding influence in forest management deserve special attention. Some NGOs focus on environmental, conservation and protection aspects of forest management. Others are concerned with rural development and poverty alleviation and actively promote the participation of rural people in tree growing and management as well as in the processing and sale of non-timber forest products as part of self-help rural development programmes. Still other NGOs concentrate more on the socio-economic and cultural aspects of development among forest dwelling communities and indigenous peoples. These different types of NGOs play a useful role in underlining sustainability in forest management, and their cooperation should be actively sought.

Local organizations of rural users of the forest or of small tree-growing farmers deserve special consideration. Their importance lies in the rules and rewards commonly accepted by a group of people wanting to be organized. When such local organizations are lacking or are weak, it is much more difficult to promote and support local sustainable forest management initiatives that take full account of local needs and experiences. Local organizations are particularly important when forests constitute a common pool of resources, with fuelwood, fodder and foods as major components of the local economy, filling gaps and providing complementary income and inputs. Almost everywhere, government appropriation or privatization has disrupted local control and management of these common property resources and resulted in increased hardship for the poor. Recently, common property management and joint management of public forests with local communities have received renewed attention in development efforts towards sustainable forest management. It is essential that public forestry institutions recognize the responsibility of local user groups in planning, managing and checking forest management prescriptions.

Adequate institutional arrangements and the capacity to implement them are critical supporting elements for sustainable forest management. The best policies and laws will not enhance sustainable forest management if the human and infrastructure capacities of the institutions remain totally inadequate, as is the case in so many countries. Furthermore, the only workable approach is partnership based on some sort of harmony and convergence of efforts between forestry departments, the private sector, rural people and other interest groups; such partnership does not preclude differences of interests but it works positively towards recognizing these interests and resolving possible conflicts in order to ensure fair shares of sustainable benefits.

INFORMATION, COMMUNICATION AND TRAINING

Ultimately, forest management will be sustainable only if its continuity is built on a strong human resource base, providing support and skills. This section deals with the need to spread knowledge, to reinforce the social base of sustainability through understanding and dialogue and gradually to strengthen technical skills and capabilities.

Information involves documenting positive ideas and developments and diffusing the information in appropriate formats to generate support for suitable solutions. Recently, forestry circles have increasingly realized that some of the misconceptions in the public debate on forest management stem from a lack of public relations capacity. Adequate information activities are essential to build up common understanding and interaction among partners concerned with sustainable forest management and to ensure support from policy-makers and the public.

Communication involves consultation and dialogue with the various partners in forest management. Such a process must especially enable forest dwellers and other forest-dependent rural groups to express their needs, expectations and experiences from the early stage of forest management preparation. This will facilitate two-way communication to stimulate participation and support in implementing the plans. This is all the more important since forest-dependent groups are among the poorest in rural areas. Furthermore, communication generates convergence among groups when different interests may require negotiations and mediation.

Education should ensure that enough people are adequately trained to design and implement the new types of forest management plans. At present, human resources constitute one of the most severe constraints, as forestry technicians may frequently be responsible for managing tens of thousands of hectares of tropical forest, and their skills are often notably insufficient for these responsibilities. Forestry schools' curricula need to be geared to the new generations of forestry technicians and professionals and should incorporate the new approaches and practices of sustainable forest management. Furthermore, staff currently on duty need in-service and refresher training to face the new orientations and complexities of sustainable forest management. Training programmes should also include private sector staff and rural community leaders.

In many cases, significant effort is required to strengthen national and local forestry and related training institutions so that the necessary skills are made available promptly in significant quantity. Training quality should be selectively improved to produce forestry personnel with a solid technical knowledge in forest management and a committed focus on sustainability.

CONCLUDING REMARKS

This paper stressed recognized key determinants of forest management performance, which the new emphasis on ecological and socio-economic sustainability has made more complex. The issues raised are treated in a general manner and need to be related to specific situations. In some cases, major policy and institutional reforms may appear to be necessary. In most cases, however, what is at stake are the attitudes of institutions and people and their willingness or, on the contrary, inertia to change their traditional emphasis and to focus on the more comprehensive and partnership approaches required in sustainable forest management.

Attitudes and capacities at national and local levels are ultimately the critical elements for any sound policy, well-designed regulation or responsible institution to have an actual and effective impact on spreading sustainable forest management practices more widely. Over recent decades, significant efforts have been made through technical assistance to build up institutional and human capacities in developing countries in line with the evolving developmental requirements of forestry. This paper largely reflects the experience gained in forestry assistance programmes and projects executed by FAO. Yet, technical assistance requirements are still very substantial and pressing. International support needs to be significantly expanded and to concentrate more on building up capacities in those critical elements of forest management and to monitor the effectiveness of results.

Finally, forestry increasingly takes place in complex interdependence among land uses and other socio-economic parameters. Thus, sustainable forest management can only be undertaken and pursued through interdisciplinary approaches within effectively coordinated rural development programmes. No sustainable forest management programme is feasible unless it takes fully into account developments in surrounding areas. Conversely, sustainable forest management programmes must be fully taken into account in development programmes concerning areas where those forests are located. Therefore, the success of sustainable forest management also depends on strengthening cooperation capacities and interdisciplinary sustainable development work across sectors in the region concerned.

People's participation in forest and tree management

M.W. Hoskins

Self-help management of trees and forests by or with rural people is potentially one of the most effective ways of sustainably managing forest resources. Yet, large forest formations are under threat of overuse by groups, including local communities. On the one hand, rural people value tree products and functions considerably; on the other hand, people are often reluctant to invest in tree management or may even jeopardize forest management. Consciousness-raising elements of projects on the importance of trees are often ineffective. The real reason for a lack of local participation is that outsiders misperceive local constraints to and attitudes towards participation. Planners and donors need to have more confidence in local people's ability to participate in all stages of activity, planning, implementation and monitoring. Important factors in this regard are institutional opportunities to improve access to and tenure over forest resources and land-use rights; using extension and research to take activities, technology and techniques to users who then extend them to other users; and changing the focus of training to these ideas of user extension and user research. Only a feeling of ownership and a guarantee of benefits will encourage local communities to take on long-term forest and tree management. This can only be provided by more appropriate institutional arrangements that benefit those who practise management and those who provide services. Definitions of the concepts of participation and institutions are also provided in this paper.

INTRODUCTION

Judging from field project reports, nothing appears more rewarding, yet more difficult to achieve, than widespread

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and effective self-help management of trees and forests by or with rural people. Not only are large forest formations under threat of overuse by groups, including local communities, but many forest formations are found in "islands", scattered throughout rural landscapes. Local collaboration is needed if both kinds of forest as well as trees are to be more effectively managed on national, communal and private lands (FAO, 1991a).

On the one hand we know that rural people almost universally value tree products and functions highly and, in some places may risk being hassled, jailed or even shot to obtain them for use or sale. On the other hand, people are often reported to be negatively predisposed towards investing in tree management. Yet again, farmers are reported to be stealing seedlings from nurseries or planting trees, sometimes collectively, in larger numbers than the forest service (FAO, 1993a). What causes this contrast in behaviour? Why may people who traditionally plant trees or manage traditional forest reserves sometimes stop doing so? (Gerden and Mtallo, 1990). Project designs very commonly include a communication campaign for "consciousness raising" on the importance of trees, but this is frequently not effective. There is something more to be learnt from studying participatory behaviour and how it is motivated.

A number of community forestry specialists have concluded that outsiders commonly misperceive local constraints to and attitudes towards participation in tree and forest management. These researchers and practitioners claim misperceptions mean that various institutions adopt dysfunctional policies and programmes, controls and reward systems and approaches, which inadvertently prevent participation. Data supporting this theory have surfaced in a number of different activity settings: watersheds (Dani and Campbell, 1986; Dove, 1992); drylands (Weber and Stoney, 1986; FAO, 1992); pastoralist systems (FAO, 1990); and shifting cultivation systems (FAO, 1991b).

But what exactly does participation mean? What are these institutions? How can these institutions change the environment to motivate self-help tree management?

THE CONCEPT OF PARTICIPATION

For our purposes, *participation is local women and men (insiders) implementing wise forest and tree management practices with adequate support, or in partnership with outsiders (e.g. forest-*

ers). Partnership or joint management is an especially important concept regarding forest resources, since most forests are legally controlled by forest services or governments. Outsiders can support local management by providing or granting access to forest resources, removing impediments to receiving benefits from their management inputs, strengthening the local organizations' situation or skills, assisting in planning, assuring that long-term benefits go to those who manage wisely, providing outside technical information, etc. Significantly, this definition implies a change of roles for both foresters and farmers in that *participation means insiders are doing some or all of the managing and forest services are really acting in a service role.* For this to happen, both farmers and foresters must see rewards from participatory management.

In many places, farmers are not participating in this way. They are deforesting unsuitable land for farming and/or overusing the forest resource base in a way that undermines future production of either trees or other plant or animal crops. Furthermore, rural people do not all want the same outputs. Community-level resource conflicts can undermine equity and sustainability. Foresters, too, frequently take on roles other than service roles. However, the authors cited above maintain that lack of participation is frequently an institutional problem and does not stem from a lack of interest or understanding. It is, therefore, important to clarify the term "institution" and identify priority institutional opportunities to increase local participation.

THE CONCEPT OF INSTITUTIONS

Political scientists have a useful definition of institutions for this context: *institutions are organizations or groups with sets of rules that cover expected behaviour, sanctions for breaking the rules and rewards for behaving in the prescribed manner* (Thomson in FAO, 1992). Organizations may codify these rules. However, in local settings, although not necessarily codified, they are understood by groups or group members.

In community forestry activities, there are three sets of institutions: at national level, including the national policy-makers who decide land tenure and other regulations and donors who often establish sanctions and rewards and exert pressure; forestry and other field-level organizations (e.g. extension services) that administer policies and have codified as well as non-codified rules of behaviour; communities or community-based groups whose members expect a certain type of behaviour towards, among other things, land, tree and forest use and management.

This definition of institutions enables the institutional rules and expectations of all actors to be examined separately or in their joint actions. It also offers the hope that institutions (rules) can change if members find the results unsatisfactory. Therefore, if farmers are not participating spontaneously in good management of forest and tree resources, the rules of expected behaviour and accompanying rewards and sanctions provided by national and local institutions need examination.

DONORS AND NATIONAL PLANNING INSTITUTIONS

An opportunity to demonstrate trust

Donors and planners have a wide range of expectations of community forestry projects, which consistently espouse local involvement in all stages of activity identification, planning, implementation and evaluation. However, most donor funded projects are designed so that local people are only involved in implementation.

In Burkina Faso, a national project director called the women to a meeting to discuss their participation in an ongoing forest management project. One woman rose and said: "As of yet we do not know what it would cost us to participate in *your* project or what would be our benefits. Once these things are clear we will let you know." Follow-up activities were then planned with the women, including a joint field trip to the forest to look at products they might want to include in the management plan.

In several host countries, such as Costa Rica, experimental funds have been established by donors to fund individually selected small activities proposed by communities themselves. This is a major step forward, although it is still the donors who finally decide on the priority and validity of the community goals.

FAO has been trying for a number of years to have projects funded by donors and accepted by host country governments which really involve local users in the whole planning process. This requires confidence that local men and women have valid objectives and can make reasoned decisions, given adequate information. Recently a five-country watershed project, funded by the Italian Government through FAO and approved by the host countries, let community members identify and plan the final objectives and activities. There is already exciting potential as people overcome their disbelief at being the ones to decide project activities. Supporting local self-help activities offers great potential for future programmes. To transfer this aspect of planning to local communities will require some changes in the rules by planners. Above all, it will require a new trust in local people to allow for the partnership approach.

NATIONAL POLICY, ADMINISTRATIVE AND LEGAL INSTITUTIONS

An opportunity to improve access and land and tree tenure/use rights and governance

Issues concerning access to or tenure over resources can largely determine the motivation of local individuals and groups in managing forests and trees. In Bolivia, villagers spoke of being interested in planting trees, but were doing so without much enthusiasm. They wanted more access to tree resources but knew large farmers could take away improved land at any time. They felt the project had not understood or provided for this threat. Tenure decisions are often made at a high policy level, not within a local or project context and often not even at the Ministry of Forestry. Yet such policies greatly influence forestry and community efforts to improve forest management and must be addressed by foresters.

Although experience shows that people with adequate access to forest resources do not always manage them sustainably, it also shows that people with inadequate resources for food security cannot practise sustainable management. It would seem that the first step in obtaining participation in management is to assure access to adequate resources and their benefits, for now and for the future.

The opportunity to provide appropriate access, however, is not always in line with current pressure to privatize forest land for individual families. Although much more needs to be known about communal management, some resources by their very nature are more effectively managed as a private individual good; others, such as some forest products, pasturelands and watersheds, are more effectively managed on a larger or community scale (FAO, 1992a). In some cases, land use changes with the season; the farmers manage individual plots during the farming season and herders use the land communally after harvest. Frequently, governmental land allocation schemes do not recognize this type of traditional, overlapping or serial tenure. In the United Republic of Tanzania, pastoralist groups are studying traditional land use to encourage the government to consider allocating larger areas of land to traditional land-use plans allowing for overlapping user rights.

Research shows various ways local people adapt to changing circumstances such as increasing tree resource scarcity. For example, local communities in Nepal developed a management system which they retained when resources were scarce and which was dropped when resources regenerated sufficiently (Gilmour and Fisher, 1991).

Both traditional and modern rules for obtaining land-use rights can provide incentives or disincentives for tree management. In a number of countries, labour is the investment that gives people land rights (Sheperd in FAO, 1993b). Unplanned deforestation and shortened fallow ensue when land is cleared of trees or farming practices to ensure land rights. In other systems, tree planting assures land tenure, and vast areas are green.

Another management incentive or disincentive concerns the definition of types of trees and access to them. In many countries, trees are controlled or owned separately from the land they are on, or species are classified differently. Recent attempts to save trees or types of trees from overuse have encouraged some governments to claim new ownership of certain species. The local reaction has been to pull up the seedlings before they are noticed so that families retain the space in the field for crops. Contrary to expectations, restrictions on sandlewood ownership in India has almost totally eliminated this tree from farmers' fields.

In a watershed programme in Thailand, farmers must plant "approved" trees on a percentage of the land to obtain land rights. While this is a positive stimulus, the species that farmers choose are often considered unacceptable by the government. Farmers value mulberry (for leaves for sericulture), jackfruit (for their valuable fruit) and other trees that provide benefits while fulfilling watershed objectives. Only a limited number of slow-growing timber trees are planted, as their benefits will never belong to the farmers.

Legal rights and an organizational forum are important for men and women farmers to address forestry and environmental problems. In Tanzania, organizational rules are being liberalized and traditional governmental bodies are again being revitalized. These local governing groups are making new rules for self-help resource management for members. This new opportunity will allow local people to improve forest management.

Therefore, the challenge for donors and policy-makers is to understand traditional local rules, effects of new laws and any attempts that local people are making to address problems of access to land and trees and to make rules concerning these resources. We must study small examples until we understand patterns. However, even before understanding all the institutional issues, local people should be supported in any attempt to improve forest and tree management and their rules regarding these resources.

EXTENSION AND RESEARCH

Opportunity to learn from users

Extension. Communication means getting messages up, down or across. The government will develop a communication "down" message to tell farmers where seedlings are located and the current market price of a product or to inform them of new laws. Farmers will develop and deliver a communication "up" message to inform policy-makers of their need for different tenure regulations or of the need to back their effort to protect a forest area. Horizontal communication will help foresters or policy-makers share experiences with colleagues in another country or enable farmers to discuss their experiences with one another.

Extension, however, involves taking activities, technologies and techniques to others. It is a form of horizontal communication of a complex set of experiences that people with full knowledge of these experiences can extend. The most exciting opportunity for forestry extensionists is to empower users to extend forestry or agroforestry practices to other users.

After professionals have helped gather the knowledge together and identify bottlenecks, their task is to provide forums for users to share and examine options. A great deal of networking is required to identify the relevant research and information about farmers' and herders' activities in other areas and then organize an opportunity for them to exchange experiences. Training may also be needed on topics from the most technical forestry technique to organizational, marketing, planning or conflict management topics.

Extension is a new field in forestry. This may be advantageous. Perhaps forestry can avoid the pitfalls of the top-down, ill-designed "messages" and "packages" which plague agricultural extension. Some planners suggest that foresters work with existing agricultural extension personnel. This could help avoid sending two, potentially conflicting, messages into the same community. It might be a good use of trained personnel in an established structure. However, where planners decide this is preferable, they will need to retrain extensionists in the particular issues that result when trees are introduced into the production and family livelihood system. These issues include:

- much more complicated tenure arrangements when the crop or plant outlives the agricultural season;
- organizational issues related to the fact that people who formerly had overlapping use rights may have their customary rights infringed when perennial species are planted;
- a much longer time-frame for planning;
- a stronger emphasis on sustainability;
- the fact that some practices in areas such as watersheds are national concerns, or are important to farmers at a distance so that rewards are not always in the same area as the management;
- the need for new market information and perhaps a new infrastructure, as forest products are often in the informal sector;
- the importance of communal management of forest resources, especially for the poor and landless;
- *most important*, the fact that outsiders (even national foresters and extensionists) seldom know all the local uses of and values placed on tree and forest products, so planning has to be approached in a two-way learning framework (Hoskins, 1987).

There are several advantages to foresters' retaining a core place in forestry extension: it allows foresters to incorporate local knowledge into their policies, planning, research and training; it helps ensure that forestry resources are valued rather than merely handled by already overstretched agriculturalists; and it reduces the risk of adopting current inappropriate agricultural extension methods into forestry.

Research. Extension and research are parallel and considered by farmers as two aspects of the same thing. In the past, most forestry and even agroforestry research centres suffered because extension was not closely related to forestry research. Research results were not adopted, even by people nearby. Research centres also suffered from inadequate inputs from farmers on research priorities.

Recently, research institutions have approached their research by learning how farmers use trees and how the farmers' own research efforts address bottlenecks in their production and livelihood systems. A new effort to develop user research has begun in Asia, with researchers and geneticists working to support farmer tree development and breeding. The farmer identifies the ideotype of the tree – exactly what function the tree should perform and in what manner. The geneticists then discuss the planting materials versus management options for obtaining the desired tree and help the farmers obtain the proper planting material and management options. Then the farmer grows and evaluates the trees in the desired place. Although this does not negate the need for basic research, more experience with farmer tree breeders will help redefine research questions.

Training

If forestry extension and research should focus on user extension and user research in areas where local participation is being sought, training for professionals to support these efforts will certainly be different. Extensionists will need to focus on new tools to elicit and organize local knowledge and help rural people identify bottlenecks. They will need to facilitate information exchange and information networks. They must help policy-makers and forestry staff understand rural realities and identify more effective rules and rewards for tree and forest management.

Foresters must know basic research methodology to help farmer research (Hoskins and Raintree, 1988). They must keep records so that they can share new information with other extensionists, strengthening information flows. These tasks will require a great deal of rethinking about curricula and the required infrastructure. One African extensionist, discussing participatory forestry efforts, reported that it would require a new approach to evaluation. As clients, the farmers should be the ones to judge the effectiveness of his work, and the previous target-oriented evaluations would no longer measure his effectiveness.

THE INSTITUTIONAL CHALLENGE

If the national and international forestry institutions' current approach is not obtaining the desired results from rural people, the rules can be examined and changed. This article has not discussed many of the fiscal policy and comprehensive planning issues necessary in successful tree management programmes. However, one major issue that donors and planners need to address is how to foster confidence and help communities develop the feeling (and reality) of ownership. Only this ownership and the guarantee of benefits will encourage communities to take on the long-term management of tree and forest resources. They must exhibit trust.

This is accompanied by the organization of management embodied in the user rights or tenure over land, trees and products. Only collaboration between local people, policy-makers and lawmakers can build on the best of traditional and current resource patterns and knowledge as well as providing appropriate support. This collaboration must take the opportunity to improve access and tenure and strengthen local governance.

Finally, forest services must become true services. Their professionals must help channel messages from communities to the policy-makers, planners and researchers as well as the more common messages to the people. They must facilitate extension between users as farmers and as researchers.

"Consciousness raising" on the importance of trees is not necessary to strengthen widespread participation in more effective tree and forest management. More appropriate rules, censures and rewards are needed that benefit those who practise management and those who provide inputs to facilitate good management.

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Research for sustainable forest management

M.N. Salleh and F.S.P. Ng

Research has an important role to play in improving the scientific basis for sustainable management of natural forests in the tropics. However forestry research in the tropics requires a long-term personal commitment from scientists and effective institutional support. Many tropical countries have been losing rather than gaining the necessary expertise. If this problem could be overcome, more attention could be given to research on urgent environmental matters, harvesting, biodiversity, non-wood resources and ecotourism.

Introduction

Forest management practices range from protection management of strict natural parks and reserves to intensive crop management of cultivated plantations. The extraction management of natural forests lies in between. The liveliest debate on sustainable forest management concerns the extraction management of tropical natural forests, particularly the question of whether we can extract from natural forests at current rates without irreversibly lowering their productivity and biodiversity.

Sustainable management of forests should strike a balance between the benefits of harvesting and the costs of regeneration. Theoretically, it should be possible to arrange to harvest only what nature replaces. However, in felling and extracting trees, the canopy is opened, soil is exposed, nutrients may be lost, habitat niches and food chains are altered and population densities of plants and animals are changed.

As far as we know, the only absolutely

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irreversible effect is species extinction. The next most serious effect is the loss of topsoil. Nutrient loss is serious because, on a large scale, it is expensive to remedy. Most other ill-effects of poor forest management can either be repaired by allowing nature to take its course for as long as needed or by speeding things up through the application of silvicultural expertise.

If extraction is dispersed in time and space, well planned and executed on moderate terrain so that there is minimal soil loss, the system repairs itself within a few decades. This has been amply confirmed where traditional shifting agriculture has been practised as well as where timber-cutting intensity has been light or limited to small areas.

However, from the 1950s to the 1970s, economists in the planning departments of many tropical countries did not accept the concept of long forest rotations; tropical foresters were forced to find ways to grow timber in 15, eight or even fewer years under plantation conditions. This undermined the case for tropical natural forest management in an indirect but pervasive manner. In many countries, a whole generation of foresters has emerged with no experience of natural forest management.

Neglect of natural forest management has resulted and will continue to result in uncontrolled degradation and destruction of natural forests. In different areas of the tropics, different levels of human impact on forests have resulted in a spectrum, ranging from mature, untouched forests through various levels of degraded forests to scrubland and finally to *Imperata* grassland.

Only within the past few years, spurred by environmental concerns, has public pressure re-emphasized natural forest management. However, opinions on objectives and management methods have tended to be polarized between strict reserves at one extreme and timber plantations at the other. There is much uncertainty over the middle ground, which is to make natural forest management an environmentally and economically viable option.

The results of research can help to keep the middle option open. Research expands the scientific basis for management on an ongoing basis and gives managers the information they need. But management itself should be ongoing and effective, not suspended "pending research".

Understanding the resource and building research capacity

Because natural forest management involves managing an ecosystem and not just a crop, the demand for scientific knowledge increases with the complexity of the system. Equally important, voluminous and unconnected data on complicated natural forest ecosystems are of little use; data have to be systematically integrated into management systems.

Basic knowledge is comparatively restricted in the tropics. In many tropical countries, for the past 50 years there has been no taxonomic research on plants and animals that could form the basis of a biodiversity management programme. Similarly, there have been few sustained attempts to carry out the periodic resource inventories necessary for intensive management. The list continues of sustained environmental research that needs to be done in ecology, physiology, silviculture, soils, forest protection, etc. Such work requires a long-term commitment: scientific training takes a minimum of three to four years for a basic degree and another three to six years for a Ph.D. Ten more years of research are needed before the better scientists may claim to be expert in their specializations. Only then do they have sufficient experience and authority to begin organizing information into systems. After that, the systems have to be continually updated and improved to meet changing demands, rectify mistakes and incorporate new knowledge.

Many developing countries have been losing rather than gaining expertise. A high turnover of research staff means research is being done almost exclusively by inexperienced scientists or short-term consultants on narrow segments of problems. Integrated research to develop management systems, combining knowledge from various fields, requires a core group of national experts to monitor developments, fill information gaps and integrate new information with old. This is what is lacking most in many developing countries, and unless this problem is solved, it will be difficult to deploy expertise in urgent and important areas such as research on environmentally acceptable harvesting techniques integrated with the management of forests for the maintenance of biodiversity, non-wood resources and ecotourism.

Environment

Environmental issues range from local and immediate to global and long-term: the local and immediate levels include the immediate impact of logging on regeneration or advance growth, through the effect of logging techniques on water supplies to the role of forests in global climate change.

The more immediate and local problems will tend to receive the most attention, but the global climate change issue is of equal priority, not least to determine the scale of the change as well as options for mitigating its effects.

Forestry will be affected by global warming because a global rise in sea level will threaten the existence of island and mangrove forests, while changes in rainfall will mean that forests in all the affected places will no longer be fully adapted to their present sites. In the past, there have been climatic changes associated with the advance and retreat of the Ice Ages, and forests advanced and retreated accordingly. Moving around is no longer possible, because land is no longer open for forest movement, nor even for the movement of people seeking economic refuge. What can be expected is that political, economic and scientific resources will be channelled increasingly into efforts to maintain patterns that were fixed under previous and present climatic regimes. Countries that have the least resources to face such change will be the most disadvantaged by it.

Harvesting

In many places, people have forgotten what a clean river looks like. Constantly muddy rivers indicate that the land is being misused on a large scale. No land can maintain its productivity, whether under forestry or agriculture, if the source of that productivity is washed away. All land users contribute to this abuse and it often starts upstream, where forests are logged with little or no consideration for soil loss.

The immediate increase in sediment load degrades fishery habitats, silts up rivers, dams, reservoirs and harbours and increases the cost of clean, piped water. All these effects are well-known and the costs of cleaning up are high, yet the abuse continues.

Research can produce cheaper and better methods of controlling erosion by critically evaluating and improving logging methods and machineries, road designs, buffer strip designs and so on. Research should also aim at exploring options for policy reform, particularly reform that will create a political and business climate receptive to erosion control. A lesson can perhaps be learnt from industrial pollution control. Twenty years ago, pollution control was viewed negatively by industries; it was at first resisted, then grudgingly accepted, then turned into profit. Now it is considered part of the total quality management philosophy that will differentiate winning corporations and nations from losing ones in the global economy. Can the same climate of change be created in forestry?

There is an interesting example in the Malaysian oil palm industry, which at first discharged its effluent into the rivers. The rivers become so badly polluted that the government had to enact and enforce legislation to control the discharge. The industry was given time gradually to meet the new standards in several stages. At first the industry protested. Then it began to do research to avoid the problem. Finally, it made profits by finding ways to convert the waste into marketable products.

In forestry, the means to reduce soil erosion during logging operations and, therefore, to improve the standard of logging, already exist, as do the means to monitor the effects downstream. These effects are not hidden. Research could refine the means, but the will to apply them depends very much on public demand.

Biodiversity

The use of biodiversity may be illustrated by the African oil palm *Elaeis quineensis*. In Africa it grows naturally in a wide range of habitats from humid to semi-arid forests; in Southeast Asia, it has been highly selected and bred in the past 50 years to produce very high-yielding plants adapted to the humid tropical lowlands. If the habitat is changed a little, to slightly drier areas or slightly higher elevations, such high-yielding palms yield less. Rubber, *Hevea brasiliensis*, has also been selected and bred to produce ultra high-yielding plants, and plantations are based extensively on clonal propagation. In all selection, breeding and cloning activities, genotypes are intensively matched to site to produce the highest possible yield of an industrial product. If there is a climatic shift, all that selection, breeding and cloning work will have to be repeated. Consequently, the protection of native variation is vital because it contains the ingredients for future selection.

Natural habitats are the best places for conserving native variation. In spite of all the claims for seed storage and *ex situ* living collections, human effort cannot parallel nature in scale or effectiveness. The difficulty in human efforts to maintain seed and living collections outside natural conditions is that such curatorial work is boring and scientists get no credit because there is little scope for discovery. The record of commitment of institutions and treasuries to unending curatorial expenditure is not always encouraging. The effectiveness of *ex situ* collections has often depended on the energy and dedication of their founders, and handing over to the next individual carries the risk that the original dedication may not be sustained even within the framework of an institution.

Nevertheless, *ex situ* conservation is the only option for the increasing number of species that no longer have, or are likely to lose, their natural habitats, as well as for cultivars that have been dis-placed from cultivation. However, hundreds of thousands of species still have natural habitats in the forests, and it is a lot safer and cheaper to conserve them there than outside. In their habitat, the species continue to adapt to the site. For example, if there is a shift in climate, scientists will have to do a lot of work to readapt crop plants to new conditions. Forests will adapt themselves through natural selection from their own pool of diversity. Biodiversity is, in fact, the basis of the self-repairing and self-sustaining capabilities of natural systems.

For commercial reasons, managers of natural forest in the past tried to shift the species balance in mixed natural forests to favour commercial species. This idea is now almost dead. In its heyday, it resulted in the mass girdling and poisoning of non-commercial trees. Nowadays, many more trees have become commercial and, in some areas, natural forest harvesting is beginning to resemble clear-cutting. The implications for the genetic composition of the regeneration have not been assessed. Indeed, forest biologists have hardly begun to consider the genetic implications of all harvesting systems, selective or otherwise. For the tropical forests, this is urgent.

In Malaysia, tree girdling was practised probably more widely than anywhere else, under the Malayan Uniform System; nevertheless, it was intended that every managed forest should have a strictly protected "virgin jungle reserve" compartment, as well as buffer strips of forest along the rivers. The will-power to implement such concepts was never strong enough. Studies should be carried out on designing and administrating such conserved forests and promoting the concepts further. On the hills of Penang Island, where the British East India Company made extensive clearings to grow spices, paintings from that period show that the hills were completely cleared of forests, leaving only the gulleys untouched. When the spice trade collapsed, the forests from the gulleys reclaimed the hills. Some lessons could be learnt from this and similar experiences elsewhere.

Non-wood forest resources

Non-wood forest resources have attracted much attention as economic alternatives and supplements to timber cutting. However, many claims for the novelty of non-wood forest resources ignore the long history of such resources. They were discovered long ago and are very well known locally, but their market shares have been stagnant or shrinking. Marketing research and entrepreneurial skills are required to open new markets as well as research into the sustained production of non-wood forest products integrated with other goods and services.

At the beginning of this century, the major economic products of tropical forests were chemical: resins, oils, rubbers and tannin. These went into a variety of products such as varnishes, pharmaceutical products, cosmetic products, insulation for electric cables and rubber products. Of these, rubber became especially important and has coexisted with synthetics thanks to major investments both in plant breeding and in marketing which have kept the natural product competitive. In the process, rubber became an agricultural crop. There has been no equivalent effort for other forest chemical products, and to regain market share will be an uphill task that must be matched by other research inputs to ensure the sustained supply.

The domestication process has started for rattans, which promise to have a good future as a raw material for attractive furniture, provided sufficiently high supplies are sustained to maintain market share. Bamboos may also have a revival provided the technologies of East Asia can be successfully adapted to the tropics.

The collection of foods from the forest has a long tradition. In Southeast Asia, practically all indigenous fruit-trees, e.g. durian, rambutan, chempedak, mango and langsat, form a genetic continuum from selected clones in orchards to genuinely wild genotypes in the forests. With such a palette of genetic materials, the future for developing new tropical fruits to suit all tastes is exciting.

After plant breeders, natural products chemists have the most creative future with forest resources. But they must have one foot in the forest and the other in the laboratory. In the forest, there are plants that one insect will eat but not another, plants that humans eat with impunity but insects and snails will not touch, and so on. To capitalize on these, scientists with an entrepreneurial spirit are badly needed.

Ecotourism

Ecotourism is another economic alternative or even supplement to timber cutting. Here, the forest manager's role has to be integrated into the overall tourism development of a region. The forest provides the scenic background and the environment for activities such as trekking, climbing and wildlife observation. At the same time, it protects the soil from being washed on to the beaches and the coral formations. The problem with ecotourism is that success can overwhelm a particular area to the extent that the building of more hotels, golf courses, roads, night clubs and casinos creates a land rush in which forests are the first to be eliminated. Ecotourism has been known to degenerate into economic cannibalism, eating into its own basis of existence. Scientists play a crucial role in conducting environmental impact assessments in all such places. Ecotourism offers the best economic potential in many small island states, but the management standards have to be particularly high because the margins for error are slim.

Social and economic research

Research needs to be carried out on social and economic issues that affect the sustainable management of all forests. Research is needed on people's perceptions of the role of forests and trees and of their requirements from them. Data are needed on the value of the services provided by the forests, which are presently largely unquantified. Only with such information can the forest manager define the objectives for forest management and determine the extent to which participatory approaches are required. Figures that quantify the benefits obtained from the forests can help to justify their existence in the face of pressures to clear them for other uses, which may offer short-term benefits, and can determine the place of forests within land-use plans.

In the past, foresters have not seen socio-economic research as a tool for the development of appropriate techniques, nor as a contribution to sustainable management. These attitudes will have to change if research is to be truly multidisciplinary and if the forestry sector is to be seen as contributing to overall rural development.

Conclusion

Many developing countries have neglected forestry research because they do not expect much from it. In our opinion, what developing countries cannot afford is second-rate research organizations, but that is what they get by neglecting research. Ideally, the difference between a rich country and a poor one should be quantitative not qualitative: rich countries can afford many scientists and many research organizations; poorer countries can afford fewer scientists and fewer organizations. However, the standard of work should be high everywhere. No matter how small, a good organization is a source of strength, whereas a mediocre organization only drains resources. This is the hard lesson that developing countries have to learn before they can achieve the kind of research needed to tackle the problems of sustainable forest management.

The basis and action required for sustainable forestry development in Chile

J.F. de la Jara

This paper describes the forestry situation in Chile and suggests viable strategies for elaborating a national policy of sustainable forest management. As of 1991, areas reforested with fast-growing species totalled 1.5 million ha, 1.3 million ha of which was *Pinus radiata*. In 1990, forestry contributed 3.3 percent to Chile's gross national product and forest product exports were worth US$950 million in 1991. This has been achieved through vigorous investment programmes in forestry by national and foreign private sector investors. For a viable policy of sustainable management, two courses of action are needed: a concerted effort by all forces in the sector to develop, by consensus, the framework within which to regulate productive, social and environmental relationships; and the assignment of technical resources by public and private agents as well as their action in the case of any difficulties.

INTRODUCTION

There is wide consensus about the concept of sustainable forestry development, which reconciles economic growth, increasingly diversified social demands and ecosystem capacity to meet such expectations. However, further exhaustive discussions are needed to elaborate operationally viable and practical approaches to sustainability.

Such approaches require basic information on a wide range of activities as well as developing analyses capable of maximizing and prioritizing social demands. Sustainability is obviously not possible to achieve when the maximum capacity of the ecosystem is unknown

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or when there are no ways of testing the sacrifices that a community or society is willing to make to meet the environmental costs of each development project.

Even when the answers to these questions are known, the subject is further complicated by the global perspective of sustainability, which may be incompatible with the basic relations of any social organization.

Nevertheless, today sustainable development is more than a simple option: it is an imperative for all major scientific, technological and political efforts.

THE FORESTRY SECTOR AND ITS PARTICIPATION IN NATIONAL DEVELOPMENT

The forestry sector is important in Chile's economy and, during the coming years, will become more so.

Chile's reserves of indigenous temperate forests total 14.6 million ha, of which 4.1 million ha are productive forests. The rest is protected forest, with functions oriented towards biodiversity conservation, erosion control in steep areas, tourism development, watershed protection, etc.

As of 1991, areas reforested with fast-growing species totalled 1.5 million ha, of which *Pinus radiata* accounted for 1.3 million ha. The remainder constitutes various eucalyptus and native species. Annual forestation during the past ten years has averaged 82 000 ha, with an annual harvest of about 30 000 ha. This considerable increase in forest resources is building up significant raw material supplies for the future and is in keeping with current and predicted investments: for example, by 1993, the installed capacity of the pulp and paper industry will double and, by 1997, it will have trebled relative to 1988. In addition, studies indicate that there are still roughly 3 million ha of productive and accessible land suitable for reforestation with these species.

In 1990, forestry contributed 3.3 percent to Chile's GDP. Forest product exports were worth US$950 million in 1991, equivalent to 10 percent of the country's total exports. Forest products are exported to over 60 countries. The range of goods, once limited to pulp, wood and chips, now covers over 300 different products such as wood-based panels, furniture, veneers and other manufactured wood products.

This promising picture is completed by a vigorous investment programme by national and foreign private sector investors; efficient entrepreneurial management facilitated by highly qualified human resources; and socio-economic and political conditions free of major conflicts.

Nevertheless, the forest sector in Chile is not yet in equilibrium, with the main components developing at similar rates. Development is centered on just one species – *Pinus radiata* – grown in a restricted area of the country by a few private enterprises with the required technology and high-level managerial capability.

However, the value potential of forestry has been generally enhanced. In practice, this process has made the sector more dynamic by introducing technology, labour relationships and expertise from highly developed countries. Concomitantly, it has generated political and social demands that have placed the forestry sector at the same level as other traditional economic sectors.

CHALLENGES IN THE SEARCH FOR SUSTAINABLE DEVELOPMENT

The current forestry situation in Chile does not enable a viable short-term policy of sustainable development to be formulated. A first step should be a wide-ranging agreement among all related sectors and the general public on contentious issues linked to the role of natural resources and the country's level of development.

The emergence of environmental issues, the trends set by the more industrialized countries, insufficient knowledge of the present forestry situation in Chile, the conflicting interests of various groups – all these can seriously hinder the formulation of a national forest policy.

Certain issues related to underdevelopment also determine objective priorities for forestry policy. In Chile, many urban and rural people experience absolute poverty and therefore need employment opportunities and training and state assistance in terms of housing and health care as well as, at times, food security. The forestry sector is sometimes the only channel for providing such assistance because of: *i)* the low level of training required for its labour force; *ii)* its location in poor rural areas; *iii)* its economic performance in production and exports; and *iv)* its sustainable resource base.

The second element of the analysis refers to the capacity of ecosystems to tolerate ever-increasing utilization pressure. No one denies the need to preserve biodiversity, ensure watershed protection and maintain the role of forest activities in relation to water, soil and the scenic beauty of the landscape. However, there is no agreement on how to utilize forests with productive potential, including those whose composition, health and quality cannot support economically viable projects.

In summary, the first step towards further progress is to reach a consensus on issues such as economic development, rural poverty eradication, environmental protection and new social aspirations.

At the same time, it will be necessary to attempt to solve those technical or political problems which are generally identified as constraints to sustainable development. They can be grouped as follows:

- problems linked to natural resources;
- problems related to production;
- problems of an intersectoral origin;
- environmental problems;
- problems related to institutional arrangements.

Problems related to natural resources

Natural forests. Any policy formulation on indigenous natural resources is seriously hampered by a lack of basic information. There is no national inventory to provide background information on the area, volume and quality of the different forest species. There is only partial knowledge regarding the silvicultural techniques for managing the existing types of forest.

Natural forests are currently a highly impoverished and degraded resource, contributing only 10 percent to national production. Historically, natural forests were selectively utilized or destroyed to gain land for agriculture and ranching; this in turn hampered the role of forests in regulating the hydrological cycle, in sustaining biodiversity and in other environmental functions.

Plantations. Planted forests extend over 1 000 km in the central-southern zone and have been established on land that is too poor for agriculture. This considerable area of forest forms the basis for current forest development and results from legal incentives for reforestation, starting with the Forest Law promulgated in 1931.

In the short term, the plantations subsector, which includes forest industries and forest workers, can be turned into an example of sustainable management, not only because about three trees are planted for each tree cut down, but because it has earned recognition for the economic results achieved and the considerable improvement in the living conditions of workers.

However, it is still necessary to resolve the potential problems related to monoculture, such as forest health, the influence of advancing forest frontiers on rural communities and the removal of deeply rooted but technically unfounded beliefs *vis-à-vis* the impact of plantations on soil, water and wildlife.

Production

As already mentioned, only 10 percent of production is based on natural forests even though there are about 4.1 million ha of potentially productive natural forests. Thus, prompt analyses and action should be planned to integrate these natural forests into development.

This imbalance is also revealed by per caput consumption of wood and panel products. Comparing Chile to former Yugoslavia, SFR, and Portugal, which are at similar levels of development, wood consumption is only 0.15 m^3 per inhabitant, while former Yugoslavia, SFR records 0.20 m^3 and Portugal 0.42 m^3. This indicates either a national culture that prefers substitutes or a deficient productive system supplying the internal market. Whatever the reasons, low internal consumption requires more detailed analysis.

Finally, the production infrastructure shows great contrasts: highly efficient equipment is associated with the export-oriented production sector, while obsolete equipment with little mechanization can be found in the small- and medium-size enterprises.

Intersectoral problems

There are also serious impediments to sustainable forestry development in other areas of the national economy. The most striking one is insufficient infrastructure in terms of roads, railways and ports.

Forestry activities are characterized by the transport of large volumes of heavy materials. Trucks transporting lumber have severely damaged the secondary road network and part of the main road system. Owing to its age and poor maintenance, the railway system cannot meet the new demand. Finally, the ports, even when they have been modernized to meet the explosive cargo growth, are nearing their capacity limit.

There is considerable public investment in transport infrastructure, taking account of priorities besides forestry. However, the efforts of the state alone will be insufficient to solve this issue. Consequently, new alternatives are being explored, such as the possibility of private investors developing ports and roads while participating in improving the efficiency of the state railway system.

Another intersectoral concern is rural poverty. Ecosystem fragility, energy requirements and land requirements for subsistence agriculture have provoked serious erosion and degradation, creating poverty enclaves for family holdings, landless agricultural workers, pastoralists, small entrepreneurs, artisans and jobless people.

It is currently imperative to intervene in education, health and housing through an integrated strategy of rural development to allow rural people to participate more advantageously in the economy. Any delay in these interventions will aggravate the overexploitation of these ecosystems, since they are the only accessible resources for survival.

Environmental effects

Environmental problems are being tackled by establishing a system that coordinates action among the various ministries and institutions concerned, thus recognizing that environmental issues cut across many national activities. This course of action differs from that adopted by other countries which have preferred to create a special unit (such as a Ministry of the Environment).

The system does, however, have some weaknesses at present:

- Examples of all natural vegetation have not been included in the National System for State Protected Areas (SNASPE).
- Systematic impoverishment and destruction of natural vegetation as a result of soil reclamation for agriculture or cattle raising, for wood harvesting for timber and fuelwood production and/or other human activities.
- The emission of gases, toxic fluids and the handling of chemical products have created some local problems.

Problems derived from institutional arrangements

State forest services have played a fundamental role in the development of countries that enjoy sound forest development. In Chile, a policy of reducing public expenditure has undermined institutional capacity to participate actively in development. In practice, this has meant the inability to enforce present legislation, develop appropriate action such as management of state-owned forests and provide technical assistance to small forest owners who are unable to formulate and implement sustainable projects.

Likewise, forest research has not adequately responded to the need for further knowledge; and, finally, educational and extension interventions have proved ineffective since they have failed to provide enough qualified human resources in number and quality to meet development needs.

CONCLUSIONS

Sustainable forestry development is the framework that accommodates fully the overall objectives of forestry policy in response to new social realities.

This will be attained neither through a simple voluntary approach, nor by legal or verbal declarations of political leaders, and certainly not in the short term. However, it is possible to start immediately to eliminate the restrictions that hinder its implementation; therefore, this should become the target and guiding principle for development actors during the present decade.

Two courses of action should be adopted to overcome the obstacles to sustainable management of forest resources. First, forces active in the sector need to be concerted. Their interests and points of view should be heard, made known and taken into account in order to develop, by consensus, the framework within which to regulate the productive, social and environmental relationships of the sector. The second task is technical and requires public and private agents to assign resources and take action in order to overcome any bottlenecks.

Following is a list of these actions:

- Substantially improving knowledge of natural forests and creating an agency for continuous forest inventory.
- Integrating the forestry sector into a national environment policy, taking account of distinctive characteristics of the sector.
- Strengthening the position of the forestry sector when prioritizing public works in transport infrastructure; and promoting the participation of the private sector in its implementation.
- Expanding the contribution of the forestry sector to rural development.
- Reorienting the development of qualified labour at all levels.
- Promoting local forest product consumption.
- Preparing existing institutions to cope better with present and future challenges in the sector.

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Indonesia's experience in sustainable forest management

L. Daryadi

This paper provides an overview of Indonesia's experiences in sustainable forest management. The author describes the state of Indonesian forest resources and their role in national development, giving some examples to show the rapid development of forestry in the country's economy: Indonesia's share of the world's plywood market reached close to 50 percent in 1988 while its sawnwood exports accounted for about 17 percent of the world market; export earnings from forest products exceeded US$3 billion in 1988 and reached about US$4 billion in 1989. Indonesia's forestry development plans and long-term perspectives, weaknesses and strengths are considered. The paper also describes Indonesia's National Forestry Action Programme. In this programme, management emphasizes five main areas: using tropical forest for soil and water protection; developing efficient industry and securing the market for forest products; utilizing timber as a renewable fuel and energy source; conserving flora and fauna as genetic resources; and promoting institutional capability and popular participation.

Forests and global environmental issues

Forests and forestry have never been highlighted as much as today. Forests not only provide essential products for survival and socio-economic development, but are also important in maintaining a sound living environment by producing commodities; contributing to soil and water conservation and desertification control, etc.

There is much public concern about deforestation and the degradation of the

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world's forests. This deterioration of forest resources results from competition for land, inadequate management and the emission of pollutants.

The real causes of deforestation in developing countries are poverty, debt, underdevelopment and the need to meet the basic requirements of rapid population growth. Balanced views of forestry's economic, social and environmental functions in development are necessary, together with an understanding of how these functions operate and interrelate.

Forest conservation and development is not an objective *per se* but rather an instrument in the larger-scale process of achieving national and international development priorities. Thus, sustainable development and environmental issues include climate change, genetic diversity, desertification control, wildlife management, freshwater resources and the protection of fragile ecosystems and forest functions.

The United Nations Conference on the Human Environment, held in 1972 in Stockholm, brought these crucial aspects of human life to the fore. Twenty years later, the United Nations Conference on Environment and Development (UNCED) was convened in Rio de Janeiro, Brazil, to evaluate the integrated dimensions of environment and development further.

As part of the global forest ecosystem, Indonesia strives to improve its utilization and management of forest resources. This paper contains an overview of Indonesia's experiences in sustainable forest management.

Forest resources and national development

Indonesia lies on the equator; it comprises about 17 500 islands, of which 6 000 are inhabited, and stretches for 5 100 km. With a total land area of almost 195 million ha, it is the largest member of the Association of Southeast Asian Nations (ASEAN) and the most important country in Asia for tropical forests. The three largest islands (Sumatra, Kalimantan and Irian Jaya) are characterized by extensive coastal plains and inland hilly areas.

Biogeographically, the archipelago comprises two major regions: the oriental and the Australasian regions. These are separated by the Wallace Line, initially proposed to distinguish the fauna on the eastern and western parts of the archipelago. Indonesia is part of the Malaysian botanical region, whose rain forests are among the richest in the world in terms of number of flora and fauna species.

Climates range from ever-wet and semi-wet climates to semi-arid or monsoon types. Average annual rainfall ranges from 700 to 4 000 mm with a mean day temperature of 32°C, mean night temperature of 22°C, daily average humidity of 90 percent and monsoon winds outside the typhoon belt.

In 1990, the population was about 180 million people. The population is very unevenly distributed and over 62 percent are concentrated in the island of Java, which accounts for only 7 percent of the total land area. Indonesia's population grew at an average annual rate of 2 to 3 percent between 1965 and 1980, but a successful family planning programme is lowering this rate. In 1989, the Indonesian labour force numbered about 74.5 million.

Indonesian forest covers around 144 million ha of land area of which 113.5 million ha have been designated as permanent forest. Dipterocarps, the dominant timber species of Indonesia, are distributed mainly in the outer islands of Java. About 3 million ha of plantation forests are dispersed in Java.

During the last 25 to 30 years, Indonesian forestry has changed rapidly. In the early 1960s, timber production was confined mostly to teak plantations in Java and a limited number of valuable species in the more accessible natural forests of the outer islands. Since then, the major setting of forestry activities has moved from Java to the outer islands. During the last 30 years, annual log production increased from 1.4 million m^3 in 1960 to 31.4 million m^3 in 1989, with about 96 percent coming from natural forests.

A minor producer and exporter of tropical hardwood logs in the early 1970s, by the mid-1980s Indonesia was a major producer and exporter of manufactured forest products. Indonesia's share of the world's plywood market reached close to 50 percent in 1988. In that year, Indonesian sawnwood exports accounted for about 17 percent of the world market.

In 1988, Indonesia produced about 9.8 million m^3 of sawntimber and about 8.2 million m^3 of wood-based panels. In that year, exports amounted to 6.9 million m^3 of wood-based panels and 3.5 million m^3 of sawnwood. Forest product exports exceeded US$3 billion in 1988, and reached about $4 billion in 1989. In 1987, forestry contributed about 16 percent to Indonesia's total export earnings, or about 27 percent of non-oil exports.

In 1988, about 64 percent of the sawnwood and 16 percent of the wood-based panels produced were consumed domestically. From 1961 to 1987, domestic sawnwood consumption per 1 000 persons increased from 18.09 to

38.2 m^3; panel products from 0.1 to 7.3 m^3; and paper and paperboard from 0.6 to 4.7 tonnes. In 1987, estimated national consumption of fuelwood (mostly from home gardens and non-forest lands) was about 115 million m^3.

Forestry, together with forest-based primary and downstream industries, is an important sector in the Indonesian economy. In 1987, forest management contributed 1.2 percent to Indonesian GDP, and the forest-based industries another 1.5 percent, bringing the total for forestry to 2.7 percent. In the same year, agriculture and fishing contributed 25.5 percent. The plywood industry is currently the most important forest industry, contributing 56 percent to the sectoral added value. Sawnwood contributed 21 percent, and pulp and paper manufacturing contributed around 10 percent.

There are also considerable backward and forward linkages for forestry and forest industries. The forest product industries have many interindustry transactions which raise the proportion of these intermediate inputs above the average for the economy.

In 1987, forestry and forest industries contributed approximately 1.2 percent to total employment. Forestry employment is widely distributed and in certain places forestry or forest industry jobs form the basis of whole settlements. Additionally, the statistics only concern direct employment and ignore attributable employment in downstream industries such as furniture making, wood carving and others. Input-output tables for the Indonesian economy suggest that, for each job in forestry, there will be 1.18 jobs elsewhere. The employment multiplier for sawmilling and plywood industries is 1.47, and 2.06 for pulp and paper.

Including direct and attributable employment in the formal sector as well as labour components in the informal subsistence sector, forestry is estimated to provide a livelihood for about four million families.

National forest policy and implementation

The basic Forestry Law, as stipulated in Act No. 5 of 1967, indicated that forests are managed according to their function, which is characterized by physical, biological, climatological and ecological factors. Technology, social and institutional values and the life supporting system should also be considered. For these purposes, there are four major forest land uses: protection forest, conservation and recreation forest, production forest and conversion forest.

In line with the World Conservation Strategy, Indonesia's nature management and conservation policy aims at achieving three main objectives:

- maintaining essential ecological processes and ecosystems;
- preserving genetic diversity; and
- ensuring the sustainable utilization of species and ecosystems.

This is as stipulated in Act No. 5, 1990, on the Conservation of Living Resources and their Ecosystems.

Indonesia has set aside 49 million ha of totally protected areas (TPA). These TPAs comprise 30 million ha of protected forests and 19 million ha conservation areas and represent 25.5 percent of the nation's lands; production forest constitutes 64.4 million ha and forest for conversion to agriculture and other uses 30.5 million ha.

To achieve the maximum benefit and sustained yield principles of forest utilization, policies are aimed at strengthening forest-based industries and natural resource conservation and at maintaining sustainable environmental conditions. These strategies are being implemented by encouraging the cooperation and active participation of local people, especially those living in or near forests.

Given the current development situations and constraints, high priority is given to accelerating forest inventory, establishing forest boundaries and topographical mapping of forest areas. Further emphasis is concentrated on improving forest land productivity, forest protection and nature conservation, forestry extension, forestry science and technology and education, training and management systems.

People's welfare needs to be enhanced by the improved production of goods and services and better environmental quality to meet economic development objectives. Forestry development is categorized as economic development.

Policy on sustainable development was implemented early in Five-Year Plan V (1989-1990): limiting log production to 31.4 million m^3 per year, imposing and increasing reforestation taxes, and raising taxes on sawntimber exports. Sawntimber exports and industries then significantly declined causing a temporary drop in log production as a knock-on effect. Small sawntimber factories were the most affected. However, more manufacturing wood industries developed, such as moulding, furniture and finger jointing in anticipation of export opportunities for finished products. Furthermore, there were more pulp and paper industries utilizing low quality wood from low quality forests.

A projected 1.5 million ha of new

forest plantation may not be achievable by the end of Five-Year Plan V because of serious constraints such as site identification, species selection, certified seed and seedling production and a shortage of skilled workers and contractors.

A more ambitious target was set for rehabilitating degraded forest and critical lands: 4.9 million ha of logged forest areas, 1,9 million ha of degraded protection forest and 5 million ha of critical agricultural land. Only the reforestation of degraded protection forest and critical agricultural lands has been organized well, involving local government and village communities. During the first year of Five-Year Plan V, only 400 000 ha of critical agricultural land and 40 000 ha of degraded protection forest were rehabilitated. Concessionaires were in charge of rehabilitating logged forest areas; but a lack of supervision, skilled and trained labour and site identification as well as weak organization have slowed progress.

Forest conservation and environmental protection focused on developing national parks and managing protection forest and nature reserves. Nature reserves and protection forests have not been managed consistently.

Major constraints include institutional problems related to the unclear division of responsibility between central and provincial government, underdeveloped organization, a lack of trained and skilled labour and incomplete forest boundaries.

Issues that will dominate forestry practices in the future include:

*i)*The delineation of permanent forest lands – 113.5 million ha of permanent forest will have to be delineated with functional boundaries.

ii) Wood-based industrial development – this should respond to market demands and will become another important issue in production forest and concession management.

iii) Increasing concern about tropical forest depletion and its environmental impacts – the emphasis will be on better conservation management of protection and nature reserves and better utilization management of production forest.

iv) Emphasis on regional development and the equitable distribution of income – this will become important in managing forests for local and regional benefit, especially regarding shifting cultivation, cooperative forestry and social forestry, infrastructure development in remote areas and increasing employment.

v) Increasing concern about product diversification – this will change forest management for multiple yields.

vi) Biodiversity conservation and global climate changes, which have been linked to industrial development and deforestation in developing countries.

Indonesia has responded to these issues in many different ways: programmes on increased energy diversification; environmental impact assessment procedures to combat pollution and environmental quality degradation; river cleaning programmes; the implementation of selection systems in forestry; reforestation and soil conservation programmes; improved management of national parks and reserves; coastal management programmes; the delineation of 113 million ha of permanent forest; and the regulation of protected areas. National development plans and strategies have addressed these issues for almost 25 years.

National forestry development plans

The national goals of Indonesia's forestry development plans have been influenced by the following activities:

- utilizing the mixed- tropical hardwood forests outside Java and the cultivated forests for promoting national development;
- converting certain unproductive forest lands into cultivated forests in order to achieve a higher stand volume per unit area and to produce industrial timber;
- improving and enriching less productive natural forest areas and maintaining sustainability of the productive area;
- rehabilitating and reforesting bare lands to turn them into production forest areas, forming part of integrated land management;
- establishing multiple-use forest;
- conserving natural resources to ensure environmental stability and preserve biodiversity.

Within these broad objectives, the different Five-Year Plans have focused on certain specific aspects of forestry in line with national policies: promoting forest utilization in the outer islands during Five-Year Plans I and II; rehabilitation, conservation and reforestation in Five-Year Plan III; and balancing utilization and conservation objectives in Five-Year Plan IV. Five-Year Plan V (1989-1994) focuses on the sound and sustainable management of forest resources and related institutional strengthening.

The first long-term National Forestry Plan was prepared for the period 1975-2000. This document was revised in

1986 to cover the period of 1986-2000. The second 25-year long-term development plan is now being prepared. With the start of the second 25-year development period, Indonesia will move into the economic take-off stage, building on the achievements of, and conditions developed by, Five-Year Plans I to V.

Long-term development planning consciously invokes the process of building successively on past achievements. Thus, the 25-year plan reflects long-term national goals in forestry. The opening of the outer islands for forestry development, the rapid development of forest-based industries and market achievements concerning forest products (from Five-Year Plan I through Five-Year Plan IV) typify the positive effects of conscious planning in meaningful stages.

The second long-term plan will emphasize socio-economic and regional development. The Ministry of Forestry (MOF) has initiated the long-term planning process for the forestry sector. Regular consultations between the MOF and university institutions have been arranged to organize seminars and public hearings on various subject matters: forest land use, customary rights, forest conservation, forest utilization systems, forest industry development, science and technology and other relevant topics.

If Five-Year Plan VI (1995-1999) is to achieve its intended goals in the forestry sectors, Five-Year Plan V should provide:

- an adequate database of the nature, extent and character of the forest lands and resources; and
- a realistic forest management planning and implementation programme with a genuine environmental orientation.

Activities are being implemented to satisfy the first condition. The World Bank-assisted, FAO-executed National Forest Inventory Project is under way within the MOF. The project will provide accurate maps, based on the field situations for the gazetting of the various categories of forests, and will identify areas of conversion forests to be allocated for agricultural uses.

The second condition requires protecting the entire permanent forest estate effectively; implementing national environmental regulations and integrating them into forestry regulations; adopting management systems that ensure long-term sustainable yields from all production forests; and gazetting the proposed permanent forest estate, i.e. production forests, conservation forests and protection forests, giving priority to those included under the protected area (conservation) system.

Outlook, strengths and weaknesses

Major constraints in early Five-Year Plan VI will be almost identical to those in Five-Year Plan V, i.e. organizational and institutional: especially concerning local and central government, private sector capacity to manage concessions and a lack of skilled and trained personnel, especially for managing natural forests and national parks. Internationally, environmental issues will seriously hamper the trade of Indonesian products on world markets and will continue to endanger Indonesian exports of plywood and other products.

Employment problems will dominate the development issue. During Five-Year Plan VI, labour will increase by 2.4 million units annually or a total of 12 million units in five years. The underdeveloped forestry sector, especially in forest management and regeneration, has ample opportunity to absorb such an employment demand.

In its management policy, Indonesia has tried to enhance its strengths while reducing or, when possible, eliminating its weaknesses. The strengths include the long history of forest management in Java; an established system of forest administration supported by national policies and legislation; an established forest-based processing industry; keen national awareness of the environmental influences and importance of forests; a national commitment to sustainable forest management; a strong and confident private sector involved in forestry and forest-based industry; and a significant amount of investment in the sector during the last 20 to 25 years.

Indonesia still has considerable forest resources. Unlike other countries in the region, the productive potential of forests has not yet been drastically reduced. Even assuming some deforestation and land-use changes at reduced rates, more than 40 percent of the total land area will still have forest cover. This is partly due to expected improvements in forest management and the standard of living by the year 2030. There will also be increasing areas of highly productive forest plantations.

Concerning human resources, Indonesia is fortunate to have cheap labour available. The labour force is projected to expand at an increasing rate during the next several years because of a high percentage of younger people in the population. Labour productivity and the general labour situation in the outer islands have generally improved.

Indonesia has a developed industrial infrastructure. Forest industries have developed very fast during the last decade, although development and adjustment are still needed, particularly in the pulp and paper industry and for improving the utilization of residues and wastes, while forest industries also need to be more diversified. However, these structural adjustments will be relatively easy to achieve. This presupposes removing market distortions, providing appropriate incentives to the private sector, having infrastructures in place as well as market channels that work and processing technologies available. All these need qualitative improvement.

Indonesian forest products are well established on international markets. In fact, Indonesia is now the world's dominant plywood exporter and is also well placed for sawnwood, wood products and rattan. It will be easy to move into marketing alternative and further downstream processed products.

An independent ministry is responsible for public forest administration in Indonesia. However, forest protection, conservation, forestry research and forest product processing are implemented by the private sector and regulated by the public sector. Indonesia has accumulated a wealth of experience in institutions related to policy formulation, planning strategies and developing regulatory frameworks. Moreover, Indonesia is firmly committed to sustainable forest management.

Strengths in some areas may often prompt unbalanced development. The main weaknesses of the forestry sector are caused by such imbalances. Log production in the outer islands grew so fast that it was difficult to ensure appropriate implementation mechanisms and operational supports because of inadequate infrastructure, facilities and labour. Land-use aspects did not receive adequate attention either.

The following factors highlight the weaknesses or constraints to be removed; the need for: institutional strengthening; improving efficiency in production and processing; strengthening the labour base and education and training facilities; enhancing the social and environmental contributions of forestry; reviewing the policies, strategies and legislation regarding future targets and goals; scientifically managing production forests; improving and reaching the less productive natural forests and managing the conservation and protection forests adequately; expanding the resource base by supplementing natural forest resources with timber plantations; improving research and extension facilities; and ensuring adequate controls and monitoring.

Forestry programmes under the Five-Year Plans have been addressing the sector's needs. They have helped to improve the situation but much more needs to be done to enable the sector to meet the environmental, social and economic challenges. Moreover, the experience accumulated in Java often does not apply to the outer islands without modification. Forestry research and development in the outer islands are urgently needed.

Another major issue in development is population growth. In the last ten years or so, Indonesia's population has increased by 33 million, reaching 182.6 million in 1991. This trend will continue despite successful efforts in family planning programmes. Security of forested lands will become more difficult to maintain without real concessionaire effort and local participation. Together with improving people's welfare, development must create economic growth, increasing production and jobs in all sectors. Economic growth emphasizes manufacturing industries and agriculture too much. Forest industrial growth is becoming a more serious issue as the production capacity of natural forests diminishes.

In the last 25 years, forestry development has basically been carried out by the private sector and has been export-oriented. Huge revenues generated by forestry are reinvested in forest industries, such as plywood, pulp and paper and sawnwood industries as well as in non-forestry activities. Yet, almost no revenue has been reinvested to maintain and develop natural forests.

This scant reinvestment in sustainable forest management was due to: the scarce knowledge and technology of private sector participants in tropical forest management; opportunities to invest in more profitable non-forestry business; poor-quality and poor-quantity labour in remote areas where forestry was operating; weak government supervision; and the very little international interest in natural resource pricing and development in developing countries.

In the 1970s, the emphasis on private sector forestry seemed to neglect the basic objectives of national development: harmonizing forestry development and the environment; managing forests sustainably; distributing wealth equitably, especially for local people near forests; increasing employment and business opportunities for all people; improving knowledge and technology in natural forest management; improving forestry production; and developing forest-based industries.

Emphasis on logging instead of natural forest management reduced the potential employment opportunity of forest development as well as the opportunity to develop skills and managerial capability in managing natural forests and the opportunities for large-scale participation in forestry development.

The private sector will still have a very important role in future Indonesian forestry development. However, a new kind of forestry private sector is needed to improve the beneficial sustainability of natural forests.

The National Forestry Action Programme

Indonesia is committed to concerted efforts launched by international agencies in the Tropical Forests Action Programme (TFAP). It believes that conservation efforts must be made through multidisciplinary measures, emphasizing five main programmes:

i) using tropical forests for soil and water protection to support agricultural production (Forest in Land Use);

ii) developing an efficient industry and securing the market for forest products (Forest-Based Industrial Development);

iii) utilizing timber as renewable fuel and energy resources (Fuelwood and Energy);

iv) conserving flora and fauna as genetic resources (Conservation of Tropical Forest Ecosystems);

v) promoting institutional capability (research and development, education and training, extension) and people's participation.

The National Forestry Action Programme has been driven by three policy imperatives:

Protection: protecting ecosystems, soil and water.

Production: sustaining multiple goods and services provided by forests to benefit present and future generations.

Participation: ensuring the proper consideration of the views and expertise of all people affected and involved in forest-related activities.

The subprogrammes of the National Forestry Action Programme are adopted as follows:

- Institutional and human resources development.
- Forest resource inventory and land-use planning.
- Improving forest land productivity and establishing industrial timber plantations.
- Improving the efficiency of forest-based industries.
- Conserving living natural resources and their ecosystems.
- Improving natural production forests.
- Promoting popular participation.
- Soil and water conservation.
- Forest protection.

Conclusion

Indonesia, one of the world's largest archipelagoes, still has considerable forest coverage. Historically, forests have been associated closely with the Indonesian people. Forestry has contributed significantly to the economic and welfare development of the people, especially in the last 25 years.

Indonesia tries to implement forestry policy and management by enhancing its strengths and minimizing or eliminating its weaknesses. Indonesia is committed to sustainable forestry management, and the management of tropical natural forest has improved considerably; however, there are still challenges to be faced and problems to be solved.

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Sweden: using the forest as a renewable resource

B. Hägglund

This paper considers the possibility of combining the conservation of forest resources with extensive utilization. The example is taken from Sweden but could also apply to other Scandinavian and northern European countries. With less than 1 percent of the world's closed forests, Sweden accounts for 4 percent of world paper production. Economic development has been accompanied by a steady increase in forest resources. Part of the reason for this success is that Swedish forestry has evolved in an environment that is largely characterized by positive industrial, economic and social conditions. Other reasons include consensus and stability in the political process affecting forestry; effective marketing strategies for forest products; extension services, subsidies and operational services. Historical perspectives on Swedish forestry and its development are also outlined in this paper, while problems regarding pollution and other environmental concerns are discussed.

INTRODUCTION

With less than 1 percent of the world's closed forests, Sweden accounts for 6 percent of global sawnwood production and 4 percent of world paper production. In the national economy, forest products give a big positive trade net, thus "paying" for Swedish imports of oil, food, chemicals, clothes, etc. Swedes' welfare is to a large extent founded on their forests.

The economic development of the Swedish forest sector has been accompanied by a steady increase in the forest resource. Since the first National Forest Survey (1923-1929), the standing vol-

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ume has increased from 1 800 to 2 800 million m^3. The current total harvest is about 65 million m^3 per year; the allowable cut (the volume that could be harvested sustainably), according to the latest calculations, is at least 85 million m^3 and increasing.

How has this come about? Situated between latitudes 55 and 69°N, Sweden cannot be considered a country with exceptionally favourable biological or ecological forestry conditions. To a considerable extent, the answer is found in the country's social and industrial development, combined with its proximity to the Western European market and relatively large per caput forest area – about 3 ha.

OLD TIMES

Ever since humans arrived in Sweden, there has been some interaction between forests and people. Forests were initially used for hunting, to provide fuel for cooking and as a source of raw materials for dwellings and other constructions. This "hunting and gathering" stage meant a rather harmonic symbiosis between people and forests. But when human societies learned to domesticate and grow crops, forests often became an obstacle and were burnt down. Shifting cultivation – burning the forests and planting a few crops in the ashes – was used extensively as an agricultural method in the less fertile parts of Sweden. Furthermore, cattle were grazed in the forests, thus hindering natural regeneration.

As the population grew and agriculture expanded, local conflicts occurred – for example, between agriculture and the need for construction timber. Rather detailed legislation concerning tree cutting and protection (such as oaks for shipbuilding) existed in the seventeenth century. However, these laws were not effectively supervised, nor did they constitute any rules regarding forest regeneration after the cutting. Most important, no law can stop a starving population from cutting trees for food, fuel and housing if there are no alternative ways of obtaining these basic necessities.

1800-1900

The nineteenth century brought dramatic changes to Swedish society. The population increased faster than agricultural productivity, leading to poverty and extensive emigration, mainly to the United States, during the second half of the century. In fact, about one-third of the Swedish population emigrated in that period. A lack of food also increased the pressure on forests, which were devastated in many parts of southern Sweden. Although there was never a lack of wood or forests nationally, transport difficulties created serious local wood shortages.

The nineteenth century witnessed the advent of European industrialization. Lumber demand increased and, when trade regulations were liberalized around 1850, the market was opened for Nordic lumber. The exploitation of northern Sweden's virgin softwood forests expanded rapidly. Sawmill companies bought or leased forests, often at unfairly low prices from farmers uninformed about the true value of their resources. In just a few decades, the sawmill companies bought about 25 percent of Sweden's forest lands. This created major social problems, such as landless farmers forced to leave their homes and search for new jobs in the growing industries. A rough but necessary restructuring of Swedish economic life took place, during which poor people paid the price of industrialization and better welfare for later generations.

Two key political issues arose in conjunction with this process: the right of the companies to buy land from farmers and the question of compulsory regeneration after clear-cutting. The latter issue was debated for at least 50 years in the Swedish Parliament before a solution was found.

1900-1945

A silvicultural act prescribing compulsory regeneration after clear-cutting was finally passed by the Swedish Parliament in 1903, followed in 1906 by a second law banning further acquisition of forest land by the sawmills. The passing of these laws was partly the result of a political trade-off – the politically strong farmers who still owned about one-half of Swedish forest areas accepted the silvicultural act as the "price" for the permanent control of their land. Thus, the cornerstones of modern Swedish land-use policy were set, with one law concerning who could buy land and another setting the owner's responsibilities regarding that land's use.

Since this time, the ownership pattern of Swedish forests has been stable: half of the productive forest land is directly owned by private persons, one-quarter by companies and one-quarter by society in different forms, mainly the state. Thus, three-quarters of the forests are in private hands, which means that society has to use forest policy when it wants to influence forestry. In countries where most forest land is owned by the state, the situation is quite different.

Legislation does not work without supervision. Consequently, the administration necessary for supervising the silvicultural act, the County Boards of Forestry, was set up in 1905. From the beginning, these boards were completely separate from the management of the state-owned forests. Their main instruments were extension and service through which they promoted the voluntary silvicultural and forestation initiatives which were the foundation for rebuilding Sweden's forest resources.

Initial progress was intimately linked to two key factors:

i) Increased efficiency in agriculture. Enough food was produced, former agricultural land became available for forestry and cattle grazing in the forests diminished. This was immensely important for further development.

ii) Development of the pulp and paper industry. A market for smaller trees was created, which set the economic incentives for thinning and, more generally, provided the financial basis for improved silviculture. It also enabled a shorter rotation period to be established.

Progress was recorded by a National Forest Survey, a nationwide sampling of the forest based on sound statistical principles. The first survey was started in 1923. The same year, the silvicultural act was complemented by a rule prohibiting the final cutting of young stands. Both the public and industry promoted forestation and silviculture as vitally important national tasks. This was manifest, for example, in the establishment of non-governmental organizations for afforestation and silviculture.

Not all developments could be considered progress, however. Silvicultural methods were the subject of intense debate at the beginning of the century. The concept of selective cutting instead of clear-cutting was introduced and became popular. Although research showed that clear-cutting was needed to activate microbial activity and thus create the nutrient flow necessary for successfully regenerating pool soils in a cold climate, practical forestry expanded large-scale selective cutting. One important reason for this was the low price of wood during the 1930s. Consequently, only a small area of new, young forests was established during the selective cutting period. This had long-lasting effects, including the existence of small areas of middle-aged forests today and the lack of forests ready for future final cutting. This so-called "age decline" has strongly affected modern Swedish silviculture.

A positive force behind forestry development in the 1930s was the increasing number of forest owners' associations. These associations aimed at rationalizing forestry operations, improving the knowledge of the forest owners and strengthening their position in wood price negotiations. In southern Sweden, the associations started to establish their own industries; the primary idea was to increase the demand for wood and thus increase forest value.

1945-TODAY

A new forestry act was established in 1948, incorporating the rationing of old forests with the earlier rules concerning the regeneration and cutting of immature stands. The reason for rationing was to ensure that the supply of wood and jobs was spread reasonably evenly over the forest area.

The disadvantages of selective cuttings became evident after 1945 and clear-cutting returned as the most widely practised method in forestry. Starting in the early 1950s, big restoration campaigns were launched in northern Sweden. Huge areas of residual stands were clear-cut (and often sprayed with herbicides), scarified and planted.

This restoration often yielded good silvicultural results but it created disputes with people outside forestry, especially concerning the relatively new and often ecologically questionable mechanized logging methods. Over time, these disputes escalated into serious conflicts, culminating in the mid-1970s when the use of herbicides in forestry became a key political question. Herbicides were banned in forestry in 1976.

Furthermore, in 1975 rules concerning nature conservation were added to the silvicultural act. A new act was adopted by parliament in 1979, introducing new rules for pre-commercial thinning and use of different genetic sources, etc. The new act was also more specific and concrete than the earlier ones. For example, regeneration requirements were formulated as a minimum number of good plants per hectare at a given number of years after regeneration. The legislation was combined with extensive forest inventory operations, aiming, *inter alia*, at identifying stands where conditions did not comply with the new rules. This combination formed a very efficient tool for the forest authorities, and consequently the silvicultural state of forests improved significantly during the 1980s.

Other important means for forest policy implementation are extension services, subsidies and operational service.

Extension has always played a major role in the work of the County Boards of Forestry. All methods are used, from personal guidance for individual forest owners, often in their forest, to extension in groups or classes and even mass communication through papers, etc. Silviculture and long-term planning have dominated the topics, but practical forest operations, safety in forest work, etc., are also covered. In the last few years, nature conservation has become an important topic.

Subsidies, often in combination with extension and law supervision, have been an important aid for improving forest resources. The principle has been to use subsidies to stimulate long-term measures that are not purely motivated from a short-term economic point of view: forestation is one example, reforestation in remote areas another. During the last decade, subsidies were financed by a silviculture fee, paid by all forest owners and based on the forest value. Recently, this fee-subsidy system has been abolished as part of a new economic policy for Sweden. The effects of this measure on forestry remain to be seen.

Operational service has long been part of the work of the County Boards of Forestry. Examples include the production of seedlings, operational silviculture and forest planning. It has been very important for all forest owners to be able to obtain good seedlings. At the same time, this has been an important part of the Board's financing. In later years, the forest owners' associations also offered the corresponding services and today there is a discussion concerning the extent of the state's involvement in operational services.

The different means mentioned are often integrated. At least during periods of strong emphasis on building up forest resources, this has been a most efficient and productive way of working.

The National Forest Survey has been developed constantly and has been instrumental in forming the basis for a forest "balance sheet". Nationally and regionally, it has been possible to check continuously that forests are not overcut and that proper silvicultural practices are performed, etc. The information is very precise and up-to-date. The survey has also provided information needed to forecast the development of forests under different management regimes, as the effects of different silvicultural programmes can be studied and important conclusions concerning forest policy drawn.

The survey and its results are thus used extensively in determining forest policy. As such, they more or less constitute a guarantee for the sustainability of forestry, making it possible to harmonize the dimensions of the Swedish forest industry with existing and forecast levels of sustainable yield.

Overall, the present state of the Swedish forests is rather good. Growth exceeds cut by about 30 percent. The regeneration is in good shape and most of the young and middle-aged stands are properly cleaned and thinned. But of course there are problems: the most serious one is the acidification and pollution of forest soils by airborne pollutants such as sulphur and nitrogen oxides and acids.

This is a difficult problem because the most important sources of these pollutants are industries in other countries, and yet extensive countermeasures such as liming must be performed on large areas in southwestern Sweden.

Another significant problem is that relations between environmentalists and the forestry sector are still not good, despite the fact that forestry has started giving more consideration to conservation aspects. The changes in attitude and knowledge have not been fully acknowledged outside the forestry sector.

Today, nature conservation focuses on sustaining the biological diversity in forests, especially the survival of plant and animal populations in danger of extinction. These threatened species are often associated with old forests or biotypes created by agricultural methods which are now being abandoned. In general, two methods are used to protect them: the creation of nature reserves; and proper consideration of small and critical biotopes in regular forestry. The latter aspect has, as mentioned above, become a part of the 1979 Swedish Forestry Act.

Recently, an extensive education campaign was started for forest owners and workers in order to improve knowledge of, and increase interest in, nature conservation. The campaign, "A richer forest", started in 1990 and already more than 50 000 people have bought the published materials. At the moment, politicians, environmentalists and foresters seem to agree firmly that education is the main road to a better understanding of nature in practical forestry. This agreement holds as long as we are discussing more conservative, normal methods of forestry. Ditching, heavy scarification, the use of new species and genetically improved trees, etc., are methods questioned by environmentalists who call for environmental impact statements.

The question of nature reserves, i.e. large areas set aside from forestry for nature conservation purposes, is rather complicated. There have been obvious difficulties in finding a national strategy for nature reserves, including the establishment of a goal for their total area. At present, about 9 percent of

Sweden's land area (3 percent of the productive forest land) consists of nature reserves or national parks. Most of the reserves on forest land are situated at high altitudes. Environmentalists argue for a considerably increased protected area; however, at least in northern Sweden, forestry argues that the large, existing reserves, especially in the mountain forests, are already serious obstacles to productive forestry and should not be increased. For southern Sweden, most parties agree that more reserves are needed but there is still some debate over financing. This debate has been hampered by a significant lack of knowledge regarding the environmental requirements of different species, and it is likely to continue for some time.

AND THEN?

What about the future for Swedish forestry? Of course, the future will largely depend on the commercial terms of forestry and forest products in a global perspective. Swedish forestry produces high-quality wood at generally high costs and its customer is almost 100 percent high-tech forest industry. The main strategy for the future must therefore be to use good wood in products that are expensive enough to bear a high price.

Future success depends on the industry's ability to identify and produce these products on an ongoing basis. Yet, one prerequisite is naturally that technological efficiency improves, thereby keeping costs reasonable. Environmental aspects will also be more important in the future than today.

A reasonable balance between production and conservation, based on mutual respect for different aims, must be established and promoted by all parties with an interest in the country's forests. The positive interlinkages between production and conservation are already quite strong and must be strengthened even further.

The revenue generated by industrial forestry provides the resources needed for conservation, and it is through conservation that production sustainability can be guaranteed. Forestry can also play a positive role as a sink for carbon dioxide, nitrogen and other pollutants.

Sweden's forests are situated close to the industrial sources of long-range airborne pollutants such as nitrogen and sulphur oxides. These pollutants are likely to figure prominently in future discussions on forestry. The emissions must be reduced considerably; however, forest soils may have to be limed in the short term to reduce acidity.

CONCLUSIONS

Finally, some conclusions can be drawn regarding the present state of Swedish forestry. These conclusions might apply to other countries, but the development of Swedish forestry is based on a number of circumstances that are not present anywhere else.

Social development. It is evident, in Sweden as well as in many other parts of the world, that sustainable forestry is difficult if people's elementary needs are not secured. A long-term forest development programme must therefore include food security as a high priority from the outset.

Swedish forestry has evolved in an environment largely characterized by a positive development of industrial, economic and social conditions. Forestry and forest industry have significantly contributed to this development but have simultaneously benefited from other sectors. For example, the mechanization of forest operations was technically and economically stimulated by similar but earlier development in agriculture and construction. It is difficult to say where Swedish forestry would stand without these positive synergies. For the future, certain problems could be identified. The continued development of society and industry is not as straightforward as has been the case for a long time. There is an evident risk of further population concentration in cities resulting from a fast reduction in job opportunities in forestry and agriculture. If this leads to a significant breakdown of rural infrastructure – roads, schools, services – Swedish forestry will face increasing problems. The growing importance of ecological values – recycling, etc. – will pose new challenges for forestry which might be difficult to handle during a transition period. In the long term, forestry will benefit from this development.

Markets. Swedish forestry is almost entirely based on wood for industrial use. An expanding free market for its products, comprising a wide variety of products and with a certain stability over time, is necessary for motivating investment in new forests. Clearly, it is possible to expand forest resources and simultaneously use forests for large-scale industrial purposes. I believe Sweden's forest industry represents a very positive experience which could also be used in other parts of the world.

The political process. A leading factor in the political process affecting Swedish forests has been consensus and stability. With few exceptions, the successive forestry acts reflected views already adopted by professional foresters because they reflect good forestry. I believe this is necessary during a period in which forest resources are being built up. In addition, strong links between ownership and management have been maintained and such links are positive in developing forests and forestry legislation, especially for new environmental protection laws. These laws, the majority of which are outside the forestry act, have begun to regulate forestry in detail and in a way that is new for foresters as well as being, in my opinion, not very appropriate in the long term. It is also necessary to reach consensus on these questions to obtain good results.

Development. Forests represent a truly renewable resource, providing a number of important products and services from a process involving the sun, water, carbon dioxide and nutrients. Compared with almost all other means by which humans obtain essential commodities, forestry and forest industry should be preferred environmentally. Against this background, I believe that ensuring sustainable forestry development in the world and in Sweden will be a most important task in the years to come and perhaps one of the most viable strategies for the future.

Sustainable forest conservation and development in France

J. Gadant

This paper discusses the experience of France in the sustainable management of forests. First, a distinction is made between the concepts of sustained yield and sustainable management. Sustainable management is a broader and more comprehensive concept in that it promotes action aimed not only at rationalizing harvesting but also at developing other economic, environmental, social, scenic and cultural components. French forest policy is examined from the point of view of its continuity and the permanent allocation of forest lands through legal provisions. Regionalized forestry policies and local application of forestry legislation to the needs of production and conservation are outlined. The association and partnership of all actors involved in forestry are essential prerequisites for effectively managing and conserving forests. The importance of communication in this regard is also stressed.

INTRODUCTION

Sustainable forest management was one of the important recommendations of the 10th World Forestry Congress; its implementation is the effective way to assure conservation of the world's logged or cleared forests.

French foresters are more familiar with the concept of "sustained yield", which they have been applying for many years in the management of public or communal forests under forest tenure. In this management, logging operations are planned both in time and in space. Their purpose is to regulate the volume of wood extracted from the forest as well as to ensure the conservation of the forest patrimony.

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In the present decline of the world forest patrimony, the term "sustainable" suggests the goal of forest longevity, and management the means to achieve it. This approach rejects the negative concept of foregoing all interventions to obtain total forest conservation; on the contrary, it promotes active forest actions aimed not only at rationalizing felling but also at developing economic, environmental, social, scenic and cultural components. Thus sustainability is a broader and more comprehensive concept than the mere sustained yield that French foresters know.

FOREST POLICY

Three factors are required to ensure sustainable forest management: the availability of well-trained and competent staff; research facilities that can promote knowledge in engineering forest ecosystems; and appropriate funding to cope with the long-term and low productivity of forests. What measures has France taken to ensure sustainable management? We will limit ourselves here to stressing the necessary continuity of forest policy and the permanent allocation of forest lands required.

Continuity

Forest activities are long-term in nature. It is therefore essential that national forest policy be continuous.

Public forest legislation. Stemming from the 1927 Forest Law, France's public forest legislation is drawn from all laws. It comprises logical regulations that impose certain obligations on public (state or communal) forests. These regulations, which require a competent manager (National Forestry Board), ensure the conservation of the patrimony and submit each forest to a management plan (in order to regulate fellings and interventions).

Private forests: obligations and incentives. Private forest ownership accounts for two-thirds of French forests. The public interest should be reconciled with the legitimate interests of their owners.

Limitations of ownership rights. Forest policy guarantees ownership rights. When public interest limits such rights, this is clearly stipulated in the law and may entail compensations. Limitations may include: subjecting forests of more than 25 unbroken ha to a management plan, which the owner submits for approval to the regional centre of forest ownership (a public establishment run by the profession and under the administration's control); making reforestation compulsory after the clearcutting of a softwood stand; prohibiting the depletion of a hardwood stand beyond certain limits; etc.

State incentives to private forests. Thus, the law limits an owner's rights. On the other hand, forests offer tangible biological, environmental, social and scenic benefits which cannot be quantified. Another point is that forest profitability is rare. These considerations justify the compensations that are granted to private forests, some of which are listed here:

- *Fiscal exemptions.* An owner who undertakes reforestation is exempted from paying land taxes for 30 years. For capital taxes, the exemption amounts to three-quarters of its value both for transferring and calculating annual property taxes.

However, these advantages are offset at the management level. The three-quarter exemption is accompanied by a 30-year commitment from the owner to submit his forest to sound logging under administrative supervision. Thus the service justifies the fiscal compensation by imposing sound management.

- *Financial contributions.* For the past 40 years, the National Forestry Fund has been financing active reforestation policy using a timber tax. The state also subsidizes investments in private forests. The 1985 law states that this financial aid be granted first to owners who can guarantee sound management practices and who pledge not to divide their property.

Permanent land allocation

Forest management can contribute to forest conservation only in so far as clearly defined legal provisions ensures stable land allocation to forest. Obviously, some changes are necessary but these should be exceptions, justified by public interest and sometimes subject to compensatory forestation.

A highly protective forest tenure administration ensures the integrity of public and communal forests. For private forests, various conservation measures have gradually been introduced into the Forest Law.

Clearing control. Owners are required to inform the administration of all projects involving forest clearing. The state authorities may oppose a project on the grounds of the public interest, as specified by law. Furthermore, authorized clearings are subject to a tax.

The place of forestry in rural management. In many tropical countries, forests still represent reserves of land that can be farmed as populations expand. A land-use management plan should identify the areas of total conservation; those where the preserved forest can be managed and harvested more rationally; lands available for reforestation; and the populated areas where agriculture and forestry can be combined.

This problem was discussed at the 10th World Forestry Congress (see Gadant, 1991). The Congress noted that there is no purely forestry solution to forest problems. Therefore the world's foresters should abandon their traditional isolation in order to design and ensure the protection and development of forests in the context of decentralized, integrated rural management agreed with the local populations and their elected representatives. The following two forestry problems have been solved through rural management.

In areas affected by rural exodus, forests have sometimes become overdeveloped and it has been necessary to set up norms restricting planting rights. Second, urbanization and industrial plants near towns have encroached on the forest, and a number of protective regulations have been required.

However, ad hoc and administrative applications of these restrictive regulations have proved ineffectual. The real solution lies in assigning the areas to the most appropriate forms of development following concerted management plans:

- reforestation should be preceded by agricultural and forestry zoning combined with the appropriate regulations;
- for forest protection, the demarcation of a "classified wooded area" in a land-use scheme would make any clearing request unacceptable;
- for management, a "protection forest" area classification imposes silvicultural restrictions on the manager.

Forest land management. However, this permanent allocation of forest lands also raises major land problems. This is particularly true in countries such as France, where inheritances passed from one generation to another have fragmented holdings.

Consequently, the 1985 land and forest laws provided the rural and forest manager with a wide variety of tools to promote global land reorganization: the exchange of ownership and utilization rights, both in agriculture and forestry; the development of lands that are unexploited by farming or forestry; the consolidation of fragmented farm or forest lands; agricultural and forest land management.

Because of agricultural production

surpluses, lands are now being abandoned. In a continent such as Europe, which has a large timber deficit, this land release offers attractive opportunities for expanding forests. But this can only be achieved by promoting sufficiently extensive consolidated forested areas, with good services to facilitate their management and use.

REGIONALIZED FORESTRY POLICIES

During the past 20 years, the excessive powers of an extremely centralized state have either been:

- deconcentrated to the local administrative authorities, in particular the prefectures;
- decentralized to the district communities (communes, departments, regions) responsible for land-use management.

Nevertheless, forest policy has not been decentralized and is still run by the state, which embodies the supreme control and continuity essential in forest management. The 1985 Forest Law, however, provided procedures to adapt and shape its application locally. In fact, the French forest patrimony is not homogeneous; its forests consist of a wide variety of stands required to carry out different and often contradictory functions.

Depending on the regions and the needs expressed, management should be given specific guidelines: here reforestation policy, there intensifying protective measures, elsewhere promoting recreational facilities, etc. Furthermore, differentiated policies should be implemented within the same region. It may not always be possible to reconcile production and conservation in a single forest, but separate management units consistent with priority aims can be set up: for instance, pockets of highly productive cultivated forests could reduce the pressure on nearby natural forests.

To this effect, the law prescribes that every region must prepare concerted guidance documents for managing public and private forests.

FOREST MANAGEMENT

In the debate between producers and conservationists, the 10th World Forestry Congress stated that "protecting forests means in the first place managing them and giving them an economic value". Obviously, forests will be protected better if they provide economic benefits to local communities, owners and populations.

Forest management is a long-term operation, however. Forestry interventions are spread over a long period of time; to regenerate a fir wood every 100 years, thinnings are carried out at ten-year intervals. For their own benefit as well as that of their successors, present owners should therefore bear in mind even the remotest goal they have set themselves in order to guide future managers. This management plan has been applied for many years to public forests.

In the 1960s, it became apparent that illegal logging in private forests had to be restricted. A lengthy debate ensued on how to achieve that objective: by state management, through a list of prohibitions, by administrative authorization? Wisely, the lawmakers opted for a liberal solution and gave the responsibility to the owners. The 1963 law obliged owners to manage their forests "in a way that would ensure the biological balance of the country and the satisfaction of its timber needs". The 1985 law stipulates that "the development and protection of forests are in the public interest". To guarantee these obligations, the law subjects forests of more than 25 ha to a management plan approved by the regional centre of forest ownership.

Thus, two disciplines govern forest maintenance: management, which establishes a medium-term logging and works policy; and silviculture, which implements the policy and shapes the stands.

Management

Our societies demand more and more from forests to satisfy an increasing number of needs. It is therefore essential to establish priorities, set an order of importance to their functions and to harmonize them.

The purpose of a forest management unit is to select the targets to be attained (timber production, public recreation, hunting, nature reserves, artistic arrangements, etc.) and to programme the necessary interventions (silvicultural and other) to attain them. It seeks to achieve a good balance between overproductivity and static conservation. Finally, these units maximize forest revenues, minimize environmental losses and ensure capital sustainability.

This type of management views the ecosystem for its ecological diversity and its global functions: not only timber production but the other environmental and social uses too, not only stands but also wildlife and landscape.

As Bourgenot (1965) puts it, "taking into account what can be done, [management] defines what is intended and infers what must be done".

What can be done: ANALYSIS. As the result of the past, which has marked it deeply, each forest has its own originality and personality, its topography, its soils and its microclimate. It is also called upon to play a special role suited to its economic and social environment.

The first step that managers should take is to survey the state of the ground and assess previous management. They must analyse the existing situation and make a quantitative and qualitative inventory of the stands, but they must also gather opinions and identify the local needs that forests can satisfy.

What is intended: STRATEGY. Most of the time the same forest is intended to fulfil several functions: timber production, recreation and soil protection. This multiple use can generally be achieved within a single forest; however, priorities must be set and uses harmonized.

Some functions may be conflicting or difficult to reconcile: setting up an exclusive recreational area where hunting is forbidden; creating a strict nature reserve; establishing declared hunting grounds, etc. If so, the forest must be divided into separate management units which foresters name compartments.

More generally, the fine art of the manager is to administer balances between: protection and conservation; the functions assigned to the forest; age classes of stands; trees and game; growth and logging; biological balances; etc.

What must be done: PROGRAMME. Finally, it is necessary to identify the way to achieve the envisaged goals.

First, managers select a treatment system (high forest, coppice, etc.) and a method of management. They establish an exploitability age to determine the annual area to be regenerated and identify possible annual harvesting: the surface (coppice, thinning) or the volume (high forest, extractive logging). The purpose is to reach an age class balance and to obtain a regular yield from the fellings, thus ensuring constant revenues, a steady supply of raw material to the wood industries and the preservation of the current state of the forest. The ideal situation is to harvest the volume of the annual growth each year.

To achieve their objectives, managers can use three types of measures:

- *Fellings – which generate income.* Management outlines a group of plots and establishes a schedule which plans the fellings both in time (year by year) and in space (plot by plot). A manager's actions are dictated by the schedule and the plot plan.
- *Works.* These may be either silvicultural (conversion, stocking)

or concerning forest equipment (roads, recreational facilities, etc.) and they are also mapped and implemented over time.

- *Regulations.* Regulations can impose some public interest constraints on a manager, such as setting up biological reserve or a protection forest, etc.

Silviculture

The choice of species is extremely important. In the past, the focus was on environmental suitability and timber-producing capacity. Nowadays, concerns are more rational and involve:

- the role of the species in maintaining soil fertility, e.g. the introduction of soil-improving hardwoods in a softwood plantation;
- biodiversity, e.g. the conservation and mixture of indigenous species.

Genetic selection, which has perhaps given too much importance to economic performance, will stress environmental adaptation and resistance to disease and climatic stress.

Foresters should also verify that a sound balance in game populations is maintained. When excessive, game may severely damage the stand.

However, sound felling is the silviculturists' main tool. The whole forest should be subject to fellings that regenerate stands and thinnings that improve them for increased vitality and sustainability. Dynamic forest conservation is ensured by annual or periodic timber harvesting that extracts carefully defined and localized volumes suited to regrowths and age classes.

ASSOCIATION AND PARTNERSHIP

Very recently, foresters were unknown to the general public and no one was interested in forests. Today, they both play a leading role and forest policy is now more open to environmental concerns (qualitative aspect) and land-use management (spatial aspect). For example, in France the Forestry Department has now become the Department of Rural Areas and Forests.

After being too long confined within their administrative structure and jealous of their technical skills and their prerogatives, foresters are now dealing with a society that is increasingly concerned with forests.

The 10th World Forestry Congress universally recommended that local populations be associated with implementing forestry interventions. In France, two roads can lead to this: creating greater accountability among the actors involved; and a better communication effort on the part of foresters *vis-à-vis* the general public.

Accountability

True forest protection will not be obtained through prohibitions issued by a centralized and police-like administration, but by the association and accountability of all concerned. This recommendation is primarily addressed to countries whose forests are unallocated and where management is administrative and state-controlled.

Fortunately France has a large population of private forest owners with sizeable forestry intervention power: one family out of every five owns a wooded area. For the forest authorities, they represent an irreplaceable support to the sector. The forest service only has to help them organize, form groups and invest as well as providing training.

This private forest category also includes the so-called "farm" forest: 1 ha out of 3 ha is part of a farm. With appropriate assistance and an extension effort, mobilization could contribute to developing these forest plots as well as to their monitoring and to management actions and interventions in other owners' forests nearby.

Finally, France possesses a large communal forest patrimony: one commune out of three owns a forest. These forests are administered by the National Forestry Board, which guarantees their integrity and sound management. But the municipalities that own them retain important rights and can decisively influence the promotion and protection of the forest stands in their commune. Municipalities also represent an irreplaceable link with the population. Moreover, decentralization has transferred important management powers to the district communities.

These private owners, farmers and rural municipalities are essential actors in France's forest policy. Beyond simple association, these forms of accountability are starting to influence the forestry policies of countries where forests are declining, e.g. through farm forests (agroforestry is the developing aspect) and communal forests (especially the idea of village forests). Forms of collective and individual appropriation should also be conceived in forest estates that are subject to too much state control and remote and impersonal management.

Communication

In an increasingly urbanized and industrialized society, forests become a remedy to the drawbacks of cities which are now prey to pollution and other problems. The town dweller is returning to nature and increasing claims put forward in favour of forest protection – the last genuine natural refuge – are triggering passionate debates.

Nature protection associations could be useful aids for forest managers against those clearing and polluting land. Environmentalists and foresters should fight together to safeguard forests. Unfortunately, this is not the case; forest management is often criticized and even blamed for forest decline. Why? No doubt because of a lack of dialogue.

In the past, foresters were good managers because they were able to maintain prestigious forests in their contemporary state while logging them rationally and deriving benefits.

Today, forest functions are being diversified, the demands of foresters' fellow citizens are multiplying and forest management is becoming increasingly complex. Foresters are increasingly obliged to take into account various aspirations and criticisms, and especially to answer questions regarding softwood plantations, instances of clear-cutting, etc. They do this increasingly through the media, training activities for the young, organizing forest visits and publishing extension material.

CONCLUSION

France has known periods of intense clearing during its history. French forests have been saved by land made available as a result of agricultural production surpluses and by the replacement of excessive fuelwood extraction with coal and petrol. Reforestation campaigns have increased the area of French forests from 8 million ha at the beginning of last century to 14 million ha at present. Today, further agricultural surpluses are releasing more land and opening up new prospects for forestry.

The worlds' foresters face three challenges: the decline of forests, their necessary expansion and the conservation of what has been saved.

We have tried to show that non-utilization or rules alone cannot preserve this living endowment. Only management can achieve truly sustained and sustainable conservation.

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New Perspectives for Managing the United States National Forest System

H. Salwasser, D.W. MacCleery and T.A. Snellgrove

This paper briefly describes the United States' forestry situation: relationships between people, forests, forest products and environmental quality; historical trends that have conditioned United States forests today; and the capabilities of national forests and grasslands. An example is offered of how the USDA Forest Service is responding to these issues and policy choices through a project called New Perspectives for Managing the National Forest System. New Perspectives projects have four primary purposes: to learn how to sustain ecosystems better at multiple geographic scales for a richer variety of current and future benefits and uses; to improve the effectiveness of public participation in resource decision-making; to strengthen teamwork between researchers and resource managers in carrying out adaptive land and resource management; and to integrate all aspects of land and resource management.

INTRODUCTION

Americans are concerned about the future of forests with regard to their health, wildlife diversity, resilience to stress and climate change, productivity for wood and other resources and their management for diverse uses, environmental services and aesthetics. Consequently, forestry practices are changing to ad

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dress these concerns. Forestry education and research are also changing (National Research Council, 1990). They are expanding to address new knowledge about the dynamics of forests as ecological systems and the connections between forest product technologies, forest management, economies and our society's changing values and needs.

The fundamental principles of forestry and natural resources management in the United States are not changing. Science-based land stewardship, efficiency in producing and conserving natural resources and socially responsible management to meet landowner objectives remain the bedrock of current and future directions in United States forestry.

Current changes in American forestry are good. However, substantial issues that merit attention include conflicts over the spotted owl, ancient forest and timber supply (Johnson *et al.*, 1991; Caulfield, 1990); forest sustainability (Botkin, 1990; Fri, 1991; Sample, 1991a; Gale and Cordray, 1991; Greber and Johnson, 1991); clear-cutting; endangered species; the economics of forestry decisions (O'Toole, 1988; Baden, 1991); sustained supplies of forest products, and loss of forest-related jobs.

Unfortunately, the continuing debate about United States forest issues often gives the impression of pending environmental doom (Knudsen, 1991) or the imminent loss of the last great forests in the nation (Caulfield, 1990). While this is not true, there are still valid reasons for concern over the conditions of American forests and how our society's institutions manage them.

The condition of United States forests has significant economic, social, environmental and aesthetic ramifications. But wise policy choices do not depend on emotional reactions to distorted information.

They depend on valid information regarding forest conditions and capabilities and the economic and environmental ramifications of various management options.

This paper briefly describes the United States' forest situation and offers an example of how the USDA Forest Service is responding to these issues through a new management direction and a project called New Perspectives for Managing the National Forest System.

FORESTS, PEOPLE AND THE ENVIRONMENT

Forests and national well-being

Part of the reason for such high concern about forests is that they are great sources of a nation's wealth and well-being (Marsh, 1864; Clawson, 1979; Williams, 1989; Perlin, 1991); a part of every generation's heritage of biological and cultural diversity and a part of the legacy each will leave for future generations; a nation's factory for many renewable natural resources (Frederick and Sedjo, 1991); vital organs of planetary health (Silver and DeFries, 1990); playgrounds; and also important factors in the standard of living that United States citizens enjoy.

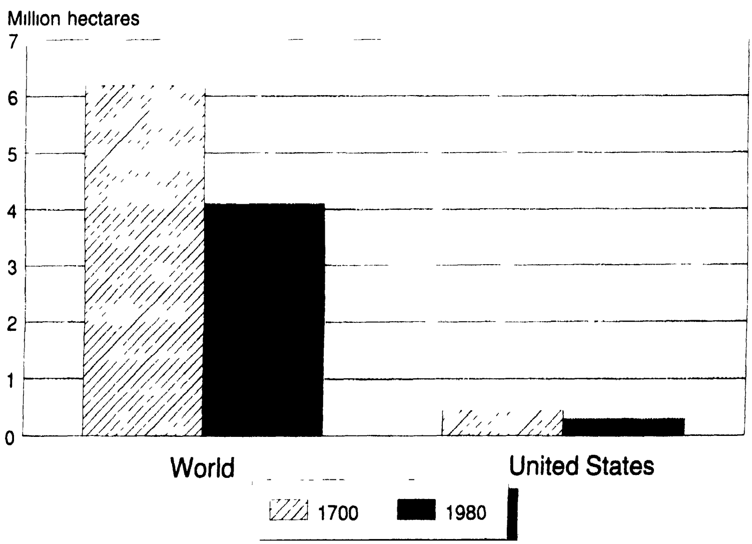
Trends in forests available for use, enjoyment and environmental services

Forests and woodlands now cover an estimated 31 percent of the planet's terrestrial surface – 4.1 billion ha (WRI). This is about 66 percent of the forested area that existed before the industrial revolution (Fig. 1). Meanwhile, population has grown elevenfold: from an estimated 500 million to about 5.5 billion.

Each world citizen had an average of about 12 ha of global forest resources in 1750; in 1990, only 0.75 ha (Fig. 2).

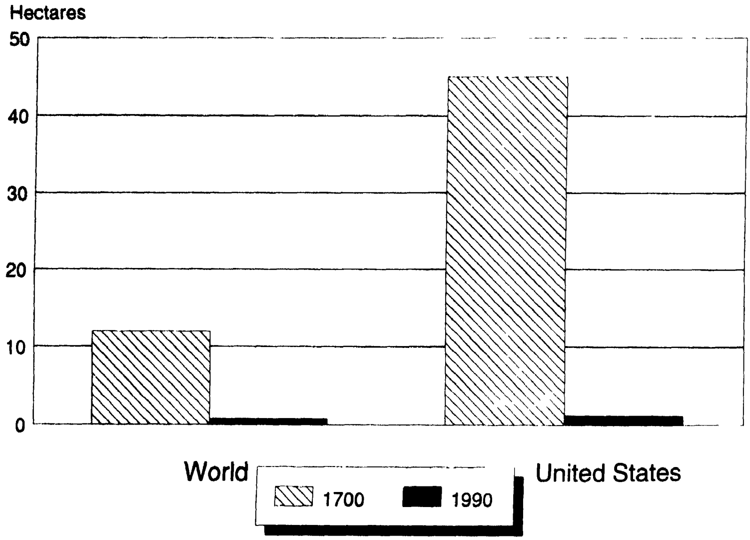
Forests in the United States cover about 32 percent of the nation's area, or 296 million ha (Haynes, 1990). This is also about 66 percent of what existed prior to European settlement (Clawson, 1979). Approximately 150 million ha of

FIGURE 1
Estimated area of land covered by forests with 10 percent or greater canopy of trees



Source Clawson (1979), WRI (1990)

FIGURE 2
Estimated change in forest area per caput from 1700s to late 1900s



the original forest have been converted to other uses, mostly agriculture, and some previously converted lands have returned to forest cover during the twentieth century (Fig. 3).

The population of what is now the United States has grown by 25 times since the 1600s: from an estimated ten million to 250 million in the late twentieth century. In other words, forested area per caput dropped from 45 ha in the 1700s to 1.2 ha in 1990 (Fig. 2).

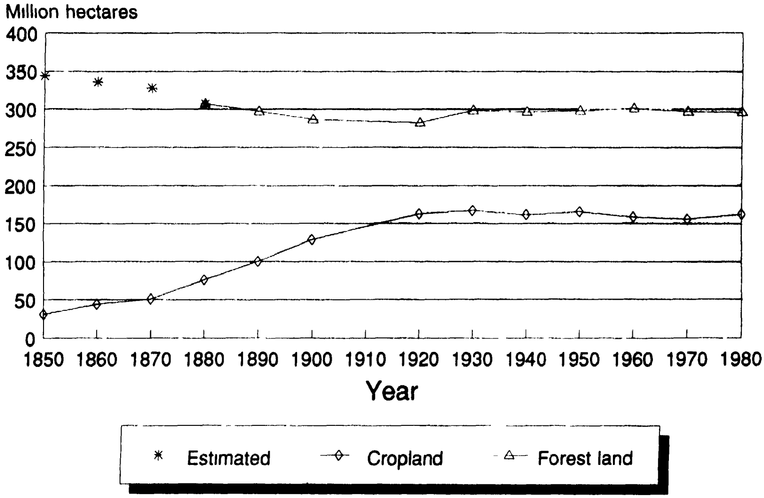
This dramatic decline in forested area per person over the past four centuries means less potential forest area for each current and future human to occupy as a residence, to find or produce resources or to provide for various environmental services.

This general trend applies to all resources in the biosphere (Fig. 4). Yet, it is precisely the growing human population, with its intellectual capacity and ingenuity, that has improved both environmental quality and standards of living for most people.

Differences in how humans use forests

People in rural areas and developing countries use forests to meet subsistence needs (Marsh, 1864; Thomas Jr,

FIGURE 3
United States land area in crop and forest cover from 1850 to 1980



Source Waddell, Oswald and Powell (1989)

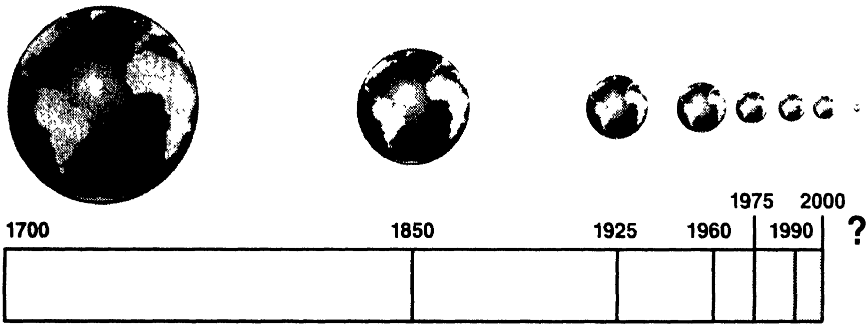
1956; Toynbee, 1976; Perlin, 1991), just as people did in the United States until well into this century (Clawson, 1979). In some cases, this relationship has been sustained for centuries and perhaps even millennia, while in others, food, shelter, medicines and fuels are taken from forests until the forest disappears or until economies develop to the point where people find their basic resources elsewhere and can afford to conserve their forests for other values.

In some developing countries, about 70 percent of the wood harvested from forests is used for domestic energy. If the human population becomes too dense, this can devastate forest sustainability.

Wood use in the United States has changed over time. In 1850, wood provided about 95 percent of the domestic and industrial energy (measured as British thermal units or BTUs) used in the United States (Fedkiw, 1989). Today, far less wood is used to supply the country's energy needs, as most of its energy comes from fossil fuel.

Between 1980 and 1988, 44 percent of all timber products in the United States was for construction (lumber, plywood and veneer); about 27 percent was

FIGURE 4
Proportional change in the area of the biosphere relative to the estimated human population over the past 300 years



for pulp and paper; and 22 percent was for fuelwood (Ulrich, 1990).

Wood consumption and supply as forest influences

Wood use has long been and still is a major influence in the relationship between people and forests (Clawson, 1979; Perlin, 1991). Both global and United States wood production and use are continuing to rise (Figs. 5 and 6; Haynes, 1990; Sedjo, 1990; Ulrich, 1990; Haynes and Brooks, 1991). The United States produces about 25 percent and uses about 33 percent of world industrial roundwood production while using about 50 percent of world paper production (Haynes and Brooks, 1991). It is both the world's biggest total user and biggest per caput user of wood (Postel and Ryan, 1991).

United States per caput use of wood other than for fuel is about 1.5 times that of other industrial countries and at least 100 times that of some non-industrial countries (Postel and Ryan, 1991). Its wood production and consumption both increased by 28 percent from the 1970s to the 1980s, primarily as a result of increased wood use in construction, home heating and wood-fuelled processes in the forest products industry (Table 1; Fig. 6; Ulrich, 1990).

Between 1980 and 1988, the United States' total net timber product imports were 9 percent of total national consumption, making it a net importer of wood products by an average of 448 000 m^3 per year. Net imports averaged 12 percent for wood pulp and 16 percent for

TABLE 1

Total United States consumption of all timber products from 1950 to 1988, including fuelwood

Years	Total United States consumption (roundwood equivalent)	Per caput consumption
	(million m³)	*(m³)*
1950-1954	340	2.2
1955-1959	337	2.0
1960-1964	332	1.8
1965-1969	362	1.8
1970-1974	372	1.8
1974-1979	411	1.9
1980-1984	466	2.0
1985-1988	542	2.2

Sources Table 4 in Ulrich (1989), Table 4 in Ulrich (1990) and United States Departments of Agriculture and Commerce

lumber and plywood products during this period (Ulrich, 1990). About 27 percent of the lumber used in the United States was imported from Canada in the late 1980s.

The United States recently produced about 23 percent of the softwood sawtimber used annually from trees harvested in the national forests. This percentage is declining as a result of policy choices to protect public forests for other values, e.g. watersheds, aesthetics and wildlife.

Will the United States use less wood as public forest production declines or will it find its wood elsewhere, such as from its private lands or the forests of other nations?

TABLE 2

Estimated energy required in the manufacture of various wall systems for building construction

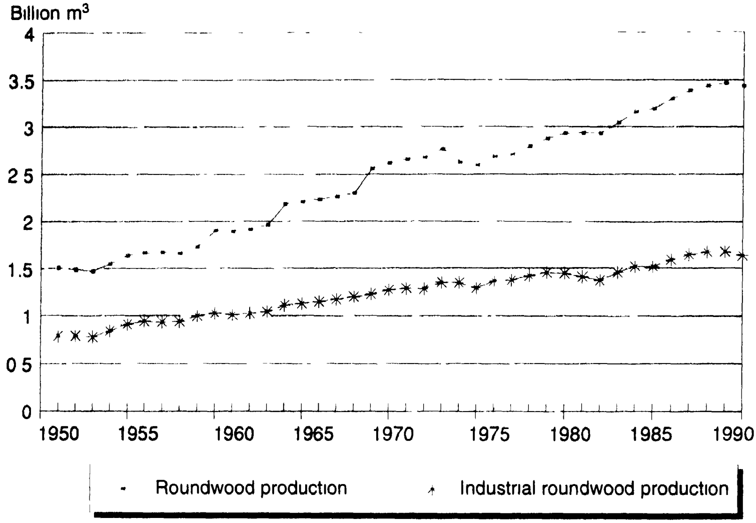
Type of wall	Energy to construct a 100 m² wall	Energy equivalent
	(million BTUs oil equivalent)	
Plywood siding, no sheathing, 2 x 4 frame	21	1.0
MDF siding, plywood sheathing, 2 x 4 frame	27	1.3
Aluminium siding, plywood, insulation board, 2 x 4 frame	53	2.5
MDF siding, plywood sheathing, steel studs	55	2.6
Concrete building block, no insulation	184	8.8
Brick veneer over sheathing	193	9.2

Note Estimates include energy consumption involved in logging (or extraction), manufacture, transport to the building site and construction
Sources Basic data are from CORRIM (1976) as cited in Bowyer (1991c) and converted to the metric equivalent

Material alternatives to wood

What if the United States substitutes non-wood materials for wood? Some materials can substitute for wood in construction applications but have both environmental and economic consequences (Table 2; Koch, 1991; Alexander and Greber, 1991; Bowyer 1991a; 1991b; 1991c)

FIGURE 5
Trend in world roundwood and industrial roundwood production from 1950 to 1990



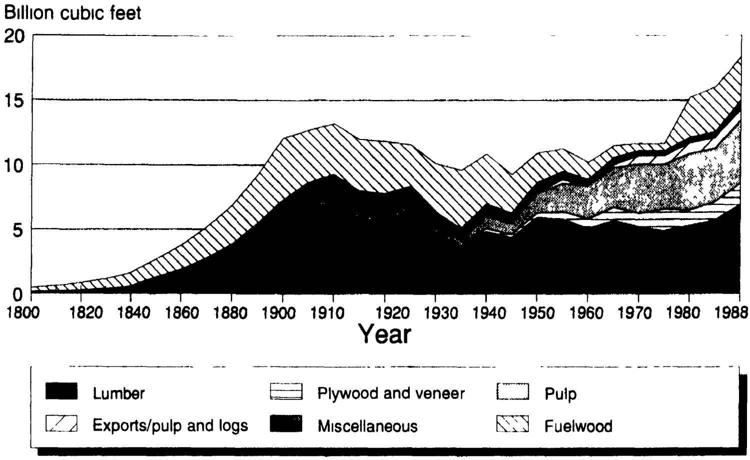
Source FAO (1991) as presented by Haynes and Brooks (1991)

Compared with its alternatives, wood is one of the most environmentally benign of all construction materials. It is virtually the only *renewable* resource that is economically suitable for structural and architectural purposes (Koch, 1991).

The alternatives to wood in those uses – steel, aluminium and other metals, concrete and plastics – are not renewable (although they are recyclable at varying energy costs). They use considerably more energy per unit of production than does wood. For example, Koch (1991) estimates that steel studs may require about nine times more energy to produce and transport to the site than wood studs.

The amount of wood used in the United States is approximately equal by weight to the combined amount of all metals, plastics and cement used in the country annually (Bowyer, 1991a). Thus, replacing any significant percentage of wood with manufactured substitutes could substantially increase both national energy consumption and global carbon dioxide emissions (Koch, 1991).

FIGURE 6
Trend in United States production of timber products from 1800 to 1988



Source Sedjo (1990) for 1800-1949, Ulrich (1989) for 1950-1959, Ulrich (1990) for 1960-1988

HISTORICAL PERSPECTIVE ON FORESTS IN THE UNITED STATES

This is not the first generation to worry about forest conditions; a look at recent history should dispel any doubts about this (Fedkiw, 1989).

In the later half of the nineteenth century, the American population was expanding rapidly, and settlement of the American frontier was considered a laudable national objective. One unfortunate consequence of settlement was the depletion of much of the nation's forests and wildlife as forests were cleared for farmland to feed a rapidly growing population and to produce lumber and structural timbers to build the growing cities. Nationally, forest growth rates were a fraction of harvest levels.

Wildlife was also under assault (Trefethen, 1975; Dunlap, 1989). There was virtually unrestricted market hunting of all kinds of wildlife for food, furs and feathers and habitats were modified through forest clearing for farms, logging and by wildfire.

By 1900, populations of many wildlife species were extremely depleted. These now include common game animals, such as white-tailed deer; wild turkey; pronghorn antelope; most furbearers, especially the beaver; many waterfowl, including swans and wood ducks and several other species of ducks; Canada geese; and all manner of plumed wading birds, such as herons, egrets and ibises. Many other species were highly depleted.

Today it is easy to criticize those responsible for resource conditions in earlier times. However, people generally do what they think is necessary to feed themselves and their families and to build their communities and nations. This period of the late 1800s and the early 1900s in the United States was a logical extension of a long settlement history. By the 1870s, the impact of settlement was magnified by a rapidly expanding population and advancing technology.

Most important, far-sighted individuals in the latter half of the nineteenth century recognized that new approaches were needed and began to take the action necessary (Trefethen, 1975).

This set the stage for emergence of the first national environmental movement. The new policy framework emphasized protecting forests from wildlife and wildlife from overharvesting while managing both forests and wildlife scientifically. Specific actions focused on:

i) acquiring scientific knowledge on forests and wildlife as well as the application of this knowledge by public and private professionals;

ii) promoting and encouraging forest protection, regardless of ownership, from wildlife, insects and disease;

iii) encouraging the productive management of private forest lands through tax incentives and technical and financial assistance;

iv) adopting and enforcing strong state and federal wildlife conservation laws;

v) acquiring and managing public lands for both commodity and amenity uses and values. A key element of the public policy framework was strong cooperation among federal, state and private sector interests.

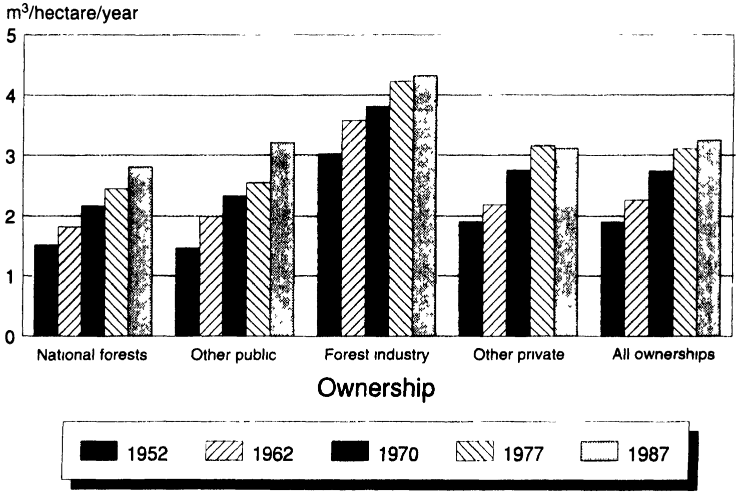
These policies resulted in the general and dramatic recovery of American forests and wildlife (MacCleery, 1991).

Forest conditions and wood use today

Today, United States forests and forest wildlife have recovered substantially. In the aggregate, the country's forest productivity has increased throughout the latter part of this century (Fig. 7).

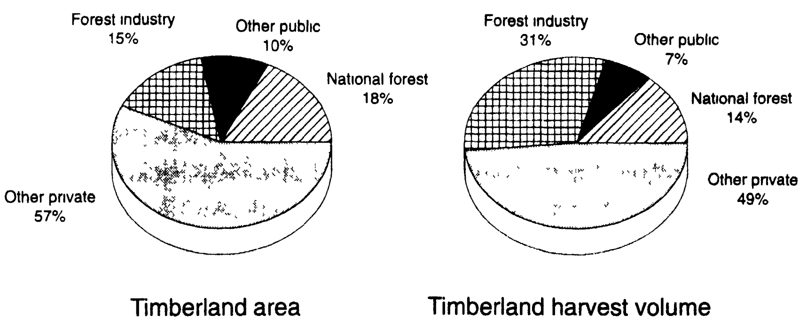
About 20 percent of the 196 million ha of United States timberland is capable of producing 1.4 m^3 of industrial roundwood per hectare annually and is not reserved for uses that preclude timber harvest (Fig. 8; Haynes, 1990). Nationwide, wood growth on these lands, which in 1900 was a fraction of wood

FIGURE 7
United States trends in net timber growth by major owner from 1952 to 1987



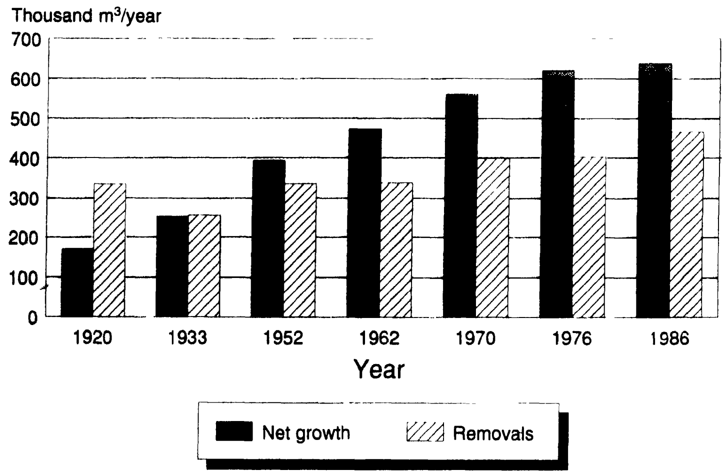
Source USDA Forest Service (1982) and Haynes (1990)

FIGURE 8
Timberland ownership as a percent of total United States timberland in 1987



Source Haynes (1990)

FIGURE 9
United States timber growth and removals from 1920 to 1986



Source Haynes (1990) and USDA Forest Service (1973, 1982)

removal, attained a general balance with harvest by the 1940s. In recent decades, average timber growth has continually exceeded harvest (Fig. 9; Haynes, 1990).

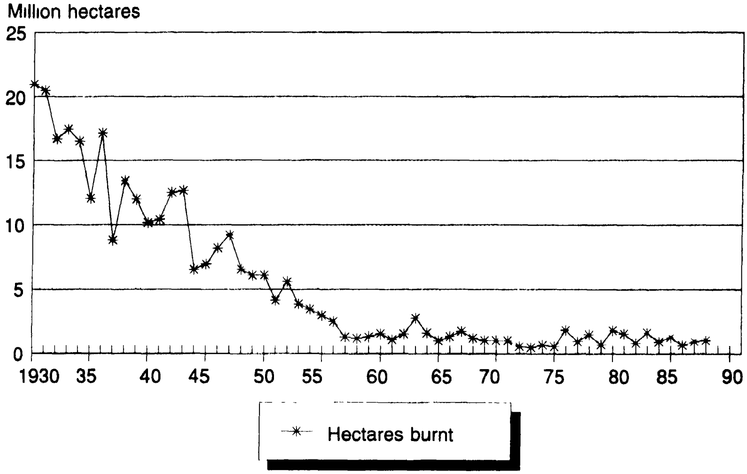
Total wood volume in United States forests is now 25 percent greater than in 1952. Actively growing forests are great carbon "sinks", and the country's forests sequester the equivalent of about 9 percent of total carbon dioxide emissions from all sources in the United States (M. Fosberg, personal communication).

Tree planting was at record levels throughout the 1980s when more than 10.5 million ha of trees were planted. This is an area the size of the state of Virginia.

Forest areas burnt by uncontrolled wildfire decreased from 1930 to 1987 (Fig. 10). We need to rethink the role of fire in keeping wildland ecosystems diverse and stress-resilient. But investments in reforestation, forest management and forest fire control have resulted in 3.5 times more forested areas with tree growth in the United States today than in 1920 (Fedkiw, 1989). This is significant because the first step in any forest conservation strategy is to maintain covered forest areas.

Owing to forest abundance and productivity, the country can protect and is protecting more of its forests, both na-

FIGURE 10
United States trends in area burnt by wildfire from 1930 to 1987



Source *Wildfire Statistics*, USDA Forest Service

tive and restored, for environmental services, aesthetic values and amenity uses. Since the late 1980s, about 14 million ha of biologically capable timberland in the United States have been designated for non-timber values and uses (Haynes, 1990), nearly double the area designated in 1970 (MacCleery, 1991).

Harvest and manufacturing efficiencies have also increased considerably since the turn of the century. Despite sketchy records, logging residues have decreased by an estimated 10 percent for softwoods and about 40 percent for hardwoods since the 1950s. Utilization of trees killed by fire, insects or diseases has also increased dramatically. Further, the proportion of harvested trees effectively converted into lumber or veneer has increased by about 20 percent in sawmills and about 22 percent in plywood plants (Haynes, 1990). Advanced technologies such as thinner sawblades, electronic measurement systems and computer-assisted milling have all contributed to improved fibre recovery.

New technologies for improved utilization, preservation and recycling have reduced by hundreds of thousands of ha the area of annual harvest otherwise necessary to supply the United States with wood products.

Even more could be done in the future to improve wood utilization and encourage recycling (Ince and Alig, 1991). Postel and Ryan (1991) estimate that conservation technologies can potentially reduce raw material demand by up to 50 percent. Conservation technologies to reduce per caput use of raw material could help take pressure off forests until population growth again raises total demand.

Forest wildlife today

Several species of American wildlife have become extinct through forest changes and human uses during this century, for example the passenger pigeon and Carolina parakeet. Many others, however, poised on the brink of extinction in 1900, have staged remarkable comebacks owing to actions set in motion in the early decades of this century (Thomas, 1989).

The pattern since the 1930s is a substantial increase in forest wildlife that can tolerate a relatively broad range of habitat conditions. Fortunately, most United States forest wildlife species are habitat generalists. One reason may be the natural dynamics of North American forests and the disturbance frequency in the natural regime.

Yet, there are still problems. Species with specialized habitat requirements are of increasing concern today. Examples include:

- the red-cockaded woodpecker and gopher tortoise, which are natives of fire-created southern pine savannahs and woodlands;
- the Kirtland's warbler, which is native of young jack pine forests in Michigan;
- the spotted owl, which occupies mature and old growth forests in the west.

Many forest wildlife species need large, contiguous areas of habitat, such as grizzly bears, wolves, elk and forest interior birds. Some require very old and ecologically diverse forests. However, it is possible to provide for the needs of habitat specialists through purposeful and often active forest management (e.g. the use of ground fires to create open savannahs and woodlands for the red-cockaded woodpecker) to recreate or maintain desired conditions and processes, although not always for early successional habitats.

Even the old growth Douglas fir forests required by the northern spotted owl are subclimax forest types that will eventually move towards different forest conditions without occasional stand-replacing wildfires.

FRAMING THE ISSUES AND POLICY CHOICES

The first challenge in policy is to seek to understand better the relevant linkages between people, natural resources, environmental service and standards of living. The second is to find ways to articulate and frame those linkages and their implications so people can make truly informed choices.

There will soon be six billion people in a place where 500 million used to live at what some perceived to be its natural carrying capacity. In the United States between 250 million and 300 million people now reside, or soon will, in an area where ten million used to live.

Americans can and should increase their efforts to conserve and recycle natural resources. Even if gains are made, however, more resources will probably be consumed in the future than now, and the resources will need to come from somewhere. Increased pollution from more consumption must also be dealt with.

On the positive side, the United States today has almost four times the human population it had a century ago, living at a substantially higher standard of living. Yet our forests and wildlife are in many ways in significantly better condition today than they were in 1890. This has significantly expanded the scope available for forest and wildlife conservation. These conditions directly result from the relative affluence and technological capacity of Americans and conscious policy choices made in the past.

The United States does, however, face significant challenges in resource management in the 1990s, including reduced energy consumption and better natural resource conservation. However, the public is unaware of past gains and the relative effectiveness of previous policy choices. Similarly, people are ill-served when environmental issues are covered so narrowly as to make it impossible for them to understand the full dimensions of choices available, or even what those choices are.

An example is the protection of the remaining stands of old growth forest in the west.

Old growth forests as a policy example

Protection of old growth forests actually started with the designation of national parks and wilderness areas in the national forests several decades ago, but Americans have been told by certain groups and the communications media that the last remnant stands of old growth in public forests are about to be logged and will disappear within a decade or two.

National forests contain about 12 to 14 million ha of old growth forest. More than half of this old growth forest is protected in wilderness areas and other land-use designations prohibiting timber harvest.

In the Pacific Northwest states of Oregon and Washington and northern California, about 2.6 million ha of old growth remain on national forest lands, about 10 to 15 percent of the original mature and old growth forest of the region. More than half of this old growth is also in wilderness and other land uses that prohibit timber harvest.

At projected timber harvest rates, about 2.3 million ha of Pacific Northwest old growth will remain in ten years. After revision to include additional protection for the northern spotted owl and other forest values (Johnson *et al.*, 1991), substantially more than 2.3 million ha of old growth will probably remain after ten years.

The policy choices are not obvious from these facts alone. The United States can accelerate the development of mature forests into old growth. However, it is important to consider how choices for protecting and managing old growth in the western United States might affect local and regional economies and environments. It is also important to consider the possible effects on national and global timber supplies, the energy and greenhouse gas implications of using substitutes for wood and the biodiversity that may be influenced by increased timber harvests in other regions and nations. We may still reach the same decisions but at least we will be aware of the larger dimensions.

Complexity and scale

Forest policy choices are complex and integrate many social values and needs as well as biological knowledge. Thus, sustainable policies will not often, if ever, be found in single-dimension choices, such as to preserve public forests and produce more wood from private lands, or save this or that species. As the ecologist Garrett Hardin (1985) has noted, it is not possible to do only one thing in an ecosystem because of the degree of interconnections.

Scale is also critical in framing questions and choices on forest policies, both in time and space. What people do to protect forests or produce forest resources in their backyards affects their own economic well-being, environmental quality and biological diversity, but it also affects other people's economic prosperity and environmental quality. This is because markets and environments are global.

There are global ramifications to the United States' consumption of fossil fuels, the worldwide use of chlorofluorocarbons, the green revolution of the 1960s, wilderness designation and high-yield silviculture. Whether these are positive or negative influences on forests, biological diversity and the quality of human life depends on how broadly and how far we view our goals for sustaining ecological systems.

We must also look outside the forest to understand the inner workings of the larger ecosystems that set the context for forests, i.e. at the regional, national and global human societies (Clark and Stankey, 1991), economies (Binkley, 1991) and environments (Silver and DeFries, 1990) that forests influence.

A national or global perspective may yield opposite conclusions from local or regional perspectives. For example, if steel, concrete or aluminium materials are substituted for the wood that is protected for environmental values in American forests, how much additional carbon dioxide will be released into the global atmosphere?

In the long term, national and global perspectives are needed because it may do little good to conserve biodiversity in local and regional ecosystems if human consumption merely depletes the same resources somewhere else. Global responsibility requires that local actions be positive nationally as well as globally.

Linking people, forests, wood, wildlife and conservation

Given the global wood supply, the large capacity to grow more wood in managed stands and the conservation potential, people may reasonably question the wholesale cutting of native old growth forests. But is it unethical to grow and cut trees in ways that leave soils, waters and ecosystems healthy for the future?

Is it environmentally ethical or globally responsible for a nation to import large amounts of any natural resource that the same nation can produce with minimal undesired consequences if it exports the environmental impacts to other nations or regions or burdens the global environment further by using less environmentally benign materials (Bowyer, 1991a)?

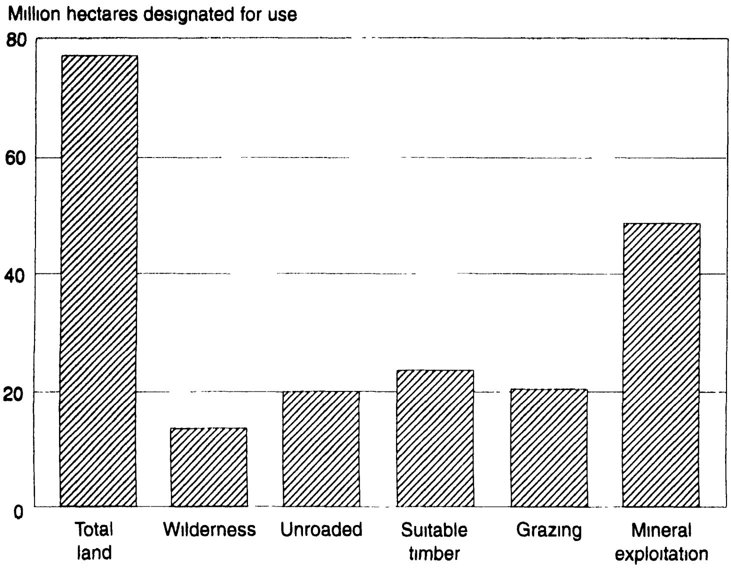
These questions indicate the challenges in forest conservation, or in what has been termed "sustainable forestry". The real challenge is to conserve forest ecosystems for desired current and future conditions, framed in a global context ensuring local and regional equity in meeting social needs.

CAPABILITIES OF THE NATIONAL FOREST SYSTEM

The United States' forests and grasslands encompass 77 million ha of land, about 8.5 percent of the national land area. They are managed under a multipurpose mandate for both commodity outputs, such as timber, livestock grazing, fishing and minerals, and for amenity uses and values, such as wildlife, recreation, nature study and wilderness. They also serve for watershed protection.

Currently, national forests play an important role both in the economy and as a

FIGURE 11
Area in different land-use designation in integrated land and resource management plans for the National Forest System in 1990 – there is an overlap in some designations, for example livestock grazing can occur in certain wilderness areas and on land suitable for timber production



source of natural and amenity values. For example, national forests provide:

- more than 70 percent of the wild and scenic river system and 84 percent of the wilderness preservation system in the lower 48 states;
- watersheds encompassing one-half of the west's water supply, 5 percent of the east's water supply, and one-half of the nation's cold water fishery;
- more than 40 percent of all federal outdoors recreation;
- habitat that supports 70 percent of the vertebrate species in the United States, including more than 200 threatened or endangered plant and animal species;
- about one-fifth of the nation's consumption of softwood timber;
- minerals and much of the current unexplored potential for oil, gas and minerals in the United States.

Recent trends in national forest timber harvesting

About 70 percent of the National Forest System is forest land. About 30 percent of that forest land is classified as being suitable for timber production, where timber harvest is permitted as one of the multiple-use objectives, along with wildlife, recreation, grazing, watershed protection and other uses and values (Fig. 11). About 2.9 million ha of the land available for timber production is of the highest productive quality for growing wood.

Nationally, annual growth of wood on national forest timberlands continually exceeds wood harvest. Growth exceeded removals by about 55 percent in 1986.

Since 1952, net annual growth of timber stock (the annual growth of timber volume minus the losses through mortality and cull volume) in the National Forest System has increased by about 67 percent (Haynes, 1990).

According to USDA Forest Service data, annual timber harvest volume from the national forests declined from about 86 million m^3 per year from 1984 to 1989, to 65 million m^3 in 1991. It could go lower if recent timber programme trends continue.

From 1984 to 1991, timber harvest for producing forest products and regenerating a new forest (clear-cutting, removal cuts and selection harvests) occurred on an average of 138 000 ha per year. This is about 0.6 percent of the area available for timber production in the National Forest System. Reforestation through planting and natural methods occurred on an average of 183 000 ha per year during this period. Intermediate harvests for improving timber stand conditions or salvaging dead, dying or diseased trees occurred on an average of 130 000 ha per year. This is slightly less than 0.6 percent of the area available for timber production. Timber harvest for special purposes such as scenic vistas and campground safety and preparation for future seed tree or shelterwood harvests, accounted for an average 9 000 ha of harvest per year.

There are 31 million ha of forest land that are not available for timber production in the National Forest System, i.e. 58 percent of the total forest area. These forests continue to change annually: through natural processes such as vegetative succession, most of which lead to a maturing forest; and disturbances such as wildfires, storms, droughts and disease epidemics, most of which induce earlier successional stages of forest.

Posing the policy questions

In recent years, the growing urbanization, affluence and mobility of Americans have virtually revolutionized the expectations and demands placed on the country's forests (particularly public forests). Some of the trends pose direct conflicts between new expectations and traditional forest values and uses.

The national forests and national grasslands can produce more wood products to meet domestic and foreign needs, they can provide more recreation, etc., but they cannot keep doing these things and others without limits or tradeoffs. Choices must be made on which uses and values to favour and how to balance management to get the best mix from a limited land base (Niemi, Mendelsohn and Whitelaw, 1991).

Because the United States is such a large force in global resource consumption and its environmental ramifications, the choices made for national forests and grasslands should consider what they are best capable of providing and the likely knock-on effects in other countries.

The essential policy question is this: given the full array of capabilities of the national forests and grasslands relative to other wildlands, and given the American people's requirements for the economic and environmental benefits of these lands, what are the desired current and future conditions, uses and values of the national forests and grasslands?

The answers will lead to further questions, such as how should these conditions, uses and values be restored, created or maintained? How should those who most directly benefit from these conditions and roles pay for the benefits or compensate those who do not benefit?

NEW PERSPECTIVES FOR MANAGING THE NATIONAL FOREST SYSTEM

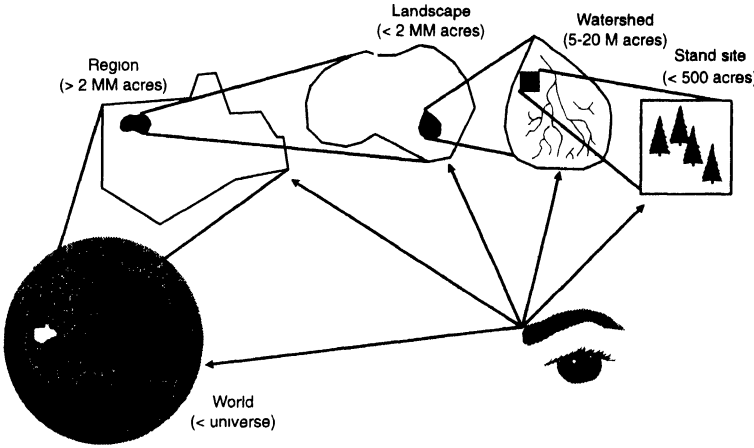
New directions

Strategic direction for managing the National Forest System is set for five-year periods under the Resources Planning Act (RPA) of 1974. The current version, the 1990 RPA Programme, identifies four themes and 19 contemporary issues for attention.

The balance of management investments among the various multiple uses is being improved through increased attention to recreation, wildlife and fisheries. Commodity production programmes are being examined and adjusted when necessary to ensure conformity to environmental protection standards. Research, resource management, technical assistance and international programmes are addressing global resource issues. Principal resource issues ranged from below-cost timber sales and clear-cutting to biological diversity and global stewardship.

Each national forest has an integrated land and resource management plan which, as appropriate, addresses these and other local issues and needs. The plans are developed and kept current through an open public involvement process, often together with conservation partners.

FIGURE 12
Hierarchy of ecosystems – ecosystem conservation requires the integration of management actions across multiple geographic scales, from sites (even microsites) to watersheds, landscapes, regions and continents



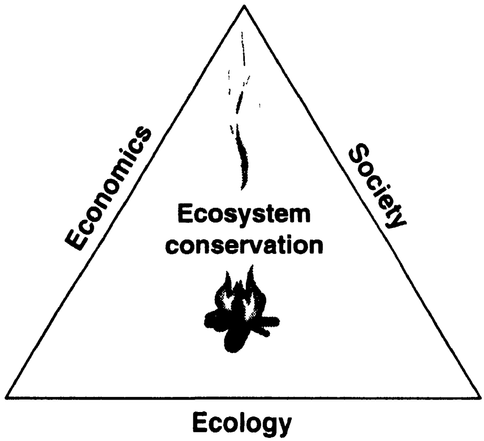
Source Society of American Foresters 1991
Task force report on biodiversity in forest ecosystems

Conserving ecosystems for broader benefits

On-the-ground projects have been established as New Perspectives projects. These have four primary purposes: *i)* to learn how to *sustain ecological systems* better at multiple geographic scales for more varied current and future benefits and uses; *ii)* to improve the *effectiveness of public participation* in resource decision-making; *iii)* to strengthen the *teamwork between researchers and resource managers* in carrying out adaptive land and resource management; and *iv)* to *integrate all aspects of land and resources management*. The projects essentially aim at improving the practical application of well-balanced, multiple-use land and resources management for broader values, uses and services.

New Perspectives projects address the broader view of wildland management that is emerging in the United States (Franklin *et al.*, 1989) and other countries (Plochmann, 1989; Maini, 1990). The Swedish call it "Rikare Skog", a richer forest (Skogsstyrelsen, 1990). It requires a landscape perspective because it is not possible to provide for all uses, values and services from every site. The foundation for this variety is the role of

FIGURE 13
Conserving ecological systems at any geographic scale requires management actions to be ecologically sound, economically feasible and socially desirable. If any of these factors is over- or underemphasized, ecosystem management goals cannot be met on a sustained basis – the "fire" goes out



biological diversity in overall land health and productivity (Society of American Foresters, 1991; Keystone Center, 1991; Hansen *et al.*, 1991; Reid *et al.*, 1992).

Conserving biologically diverse and productive landscapes is a primary theme of New Perspectives projects (Salwasser, 1991); so is the application of ecosystem concepts to managing national forests and grasslands at multiple scales. Figure 12 illustrates the multiple geographic scales of ecosystems.

Principles and guidelines for ecosystem managers

To conserve ecosystems, regardless of the specific goals, management must be: ecologically sound, economically feasible and socially responsible (Fig. 13). If any one of these elements is missing or out of balance, the desired ecosystem conditions will not be sustainable.

The key point is that there is not a single natural purpose or set of biological conditions for which particular ecosystems must be conserved. However, the biological and physical complexity of any ecosystem will define its capabilities, resilience and long-term sustainability. Therefore, it is not possible to define ecosystem conservation solely by economic or social criteria.

Ecosystem conservation can only be continually defined and refined at the intersection of three factors: ecology, economics and society. Because all three constantly change, scientifically based, socially responsive and adaptive management (Walters, 1986) is essential.

To help land stewards achieve management, there are four principles that serve as useful guides:

***Principle 1**. Taking care of the land* by protecting or restoring its soils, air, waters, biological diversity and ecological processes.

***Principle 2**. Serving the people* by helping individuals, families and communities who depend on the land for food, fuel, shelter, livelihood and recreation meet their basic needs within the sustainable capability of the land.

***Principle 3**. Improving or sustaining the economic well-being and security of communities, regions and nations* by wisely producing, using and conserving natural and human resources.

***Principle 4**. Striving for balance, equity and harmony between people and land* in meeting this generation's resource needs while maintaining similar options for future generations.

The World Commission on Environment and Development (1987) called its version of these principles "sustainable development".

The essence of conserving ecological systems at landscape and larger scales is managing for diversity: in biological systems, in economic systems and in human social systems. In a rapidly changing and unpredictable environment, all these forms of diversity are needed.

Implementing New Perspectives – taking a landscape view

Landscape management to conserve ecological systems means sustaining their integrity, diversity, productivity and resilience so the land can continue to provide the kinds of resource products, uses, values and services that people need and desire.

Foresters historically managed ecological systems for certain desired uses and conditions: for example, producing and sustaining yields of selected products, such as wood and wood fibre. Management for these purposes usually involves simplifying the system: through clear-cutting, followed by the planting of desired tree species and reducing competing vegetation.

A landscape approach to ecosystem and resource management seeks to fit management practices at different geographic scales to suit the characteristics of the land and the specific purposes for which different areas are being managed. At the extremes, this can range from the intensive culture or development for high yields of products or uses on some sites to the strictest forms of protection or ecological restoration on others. In most cases on public wildlands, it will feature less intensive forms of resource production or protection, i.e. multiple-benefits management.

Management for site or local diversity means that less of the primary productivity of some sites will be channelled to a single or few products of choice. Thus, for at least the short term, wood volume or game-wildlife yields from those sites may be lower. On the other hand, managing for diversity at a landscape or regional scale means that a larger area of land may be suitable for less intensive uses or forms of management Overall, the land's ability to sustain a wide array of values, uses and services and respond to stresses or climate change may offset short-term productivity losses. This is the ecological rationale of New Perspectives.

Landscape management to sustain richer benefits and future options does not mean that all sites receive the same treatment or serve identical purposes (Forman and Godron, 1986; Hunter Jr, 1990). Because each site can potentially serve different purposes, the challenge is to determine the balance of purposes and the mosaic of sites in watersheds and landscapes that will sustain the ecosystems.

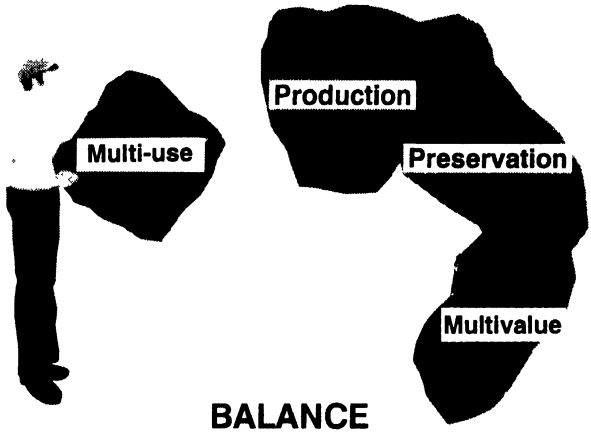
In ecosystem conservation, all potential land uses and practices are valuable. Most ecological sites can serve different purposes. Many resource and environmental goals can only be effectively addressed at larger geographic scales, such as landscapes and regions. At these scales, people are part of the ecosystems and need resources from somewhere, and some places in these landscape-scale ecosystems must protect unique environmental values. Therefore, all places in landscapes and all practices that can sustain the ecosystems or serve the needs and aspirations of people are potentially valuable (Fig. 14).

Consequently, managers and scientists must increasingly interact with people who depend on the landscape to determine how best to provide the desired balance. Integration of goals and actions; coordination of plans and projects across multiple spatial and temporal scales; and collaboration among all the interested parties – all these are necessary for managing landscapes and their ecosystems for broader benefits.

Balancing land-use classes and management direction

Forest plans have designated large areas of the National Forest System for the

FIGURE 14
Conserving ecosystems for desired values, uses, products and services requires blending the application of resource protection, restoration, management and enhancement at watershed, landscape and larger geographic scales



primary purpose of restoring and protecting native ecosystems and rare elements of biological diversity. In these areas, natural processes are encouraged, although some human intervention may be necessary to sustain desired ecological conditions, e.g. prescribed fires.

Other areas are designated for multiple benefits, including appropriate resource uses and, at times, for considerable intervention to achieve specific objectives, e.g. dispersed recreation areas, habitats for neotropical migrant birds, selective timber harvest and ungulate winter ranges. Much of the land in multiple-benefit areas will contain substantial amounts and distributions of "biological legacies" such as large, live trees, standing and fallen dead trees, native hardwoods, etc. (Franklin *et al*, 1989; Skogsstyrelsen, 1990; Hansen *et al.*, 1991; Swanson and Berg, 1991). These "legacies" contribute to the long-term diversity, productivity and resilience of ecosystems.

The National Forest System also designates substantial areas for economically efficient production of wood, energy, minerals, water, recreation and fibre to help serve the nation's resource needs. Management in some of these areas is patterned after successful private sector programmes on appropriate sites (Bingham, 1991). However, even these intensively managed wildlands will provide considerable environmental services and values: clean water, carbon sequestration, habitat for early successional wildlife and outdoor recreation.

Because the National Forest System is so diverse, productive and resilient, the locations, amounts and management direction for each of these land-use designations could vary in the future.

Choosing desired present and future conditions

The choice of what to do about United States' national forests and grasslands should address the desired present and future conditions of three things: environments, economies and the conditions of human families and communities locally, regionally, nationally and globally.

Ecosystem conservation and its subset of sustaining desired forest conditions means protecting the environment and meeting people's needs for natural resource products and services for the short and long term. The challenges in doing this can only be met by bringing people and nature together. This has been known for a long time (Prabhavananda and Isherwood, 1944; Gia-Fu Feng and English, 1972; Easwaran, 1985; Weatherford, 1988; Sahtouris, 1989; Wall and Arden, 1990).

Economic well-being and human cultural diversity are as vital to our desired future as biological diversity (Reid *et al.*, 1992). We cannot choose to have one without the others.

SUMMING IT UP: CONSERVATION IS STILL THE BEST MODEL

To address resource depletion in the late nineteenth century, conservation was offered as the model for ethical behaviour regarding forests and forest resources. It stressed protecting basic resources, scientific management, and wisely using resources to serve people's needs. Over the years, new dimensions emerged: multiple use, sustained yield, wilderness preservation, endangered species protection and integrated land management and planning.

While some problems remain and others have emerged in the last few years, on balance, multiple use and conservation have definitely worked. The conditions of United States forests, wildlife, rangelands, agricultural lands and related resources have improved dramatically during the last century, and these trends are continuing. Thus, the current resource situation in the United States offers more choices than if these policies had not been implemented.

Adding the ecosystem dimension

Ecosystem conservation for multiple benefits is an emerging model for land

and resources management in the 1990s. It is conceptually broader than the previous models of sustained yield and multiple use but builds directly on the foundation established by previous policies, concepts and accomplishments.

Because of what prior generations of political leaders, scientists and resource managers created, we can explore land management that considers more than selected resource outputs, more than single species and more than a mechanistic, reductionist view of nature.

This does not mean that controversy over forest uses in the United States will soon subside. Americans are still split over the appropriate uses of national forests and are increasingly concerned about private lands as well. This concern will not diminish until people agree on the need for diversity and the relative purposes and juxtapositions of all sites on the landscape.

More emphasis on managing national forests and grasslands for broader benefits in the future does not mean that the challenges stop at the border of distinct landownerships. These are regional and national concerns, requiring coordination among neighbouring landowners and land managers.

And we must be constantly ready for change. One thing is certain about the future: the biosphere will change whether humans want it or not. It will not be possible to conserve ecosystems and have a healthy environment in a changing world without reasonable human well-being and vice versa. Thus, education, economic development, equity in distributing resources, adaptability and conservation of natural resources must all complement good land management as the necessary and sufficient parts of a global stewardship ethic (Reid *et al.*, 1992).

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